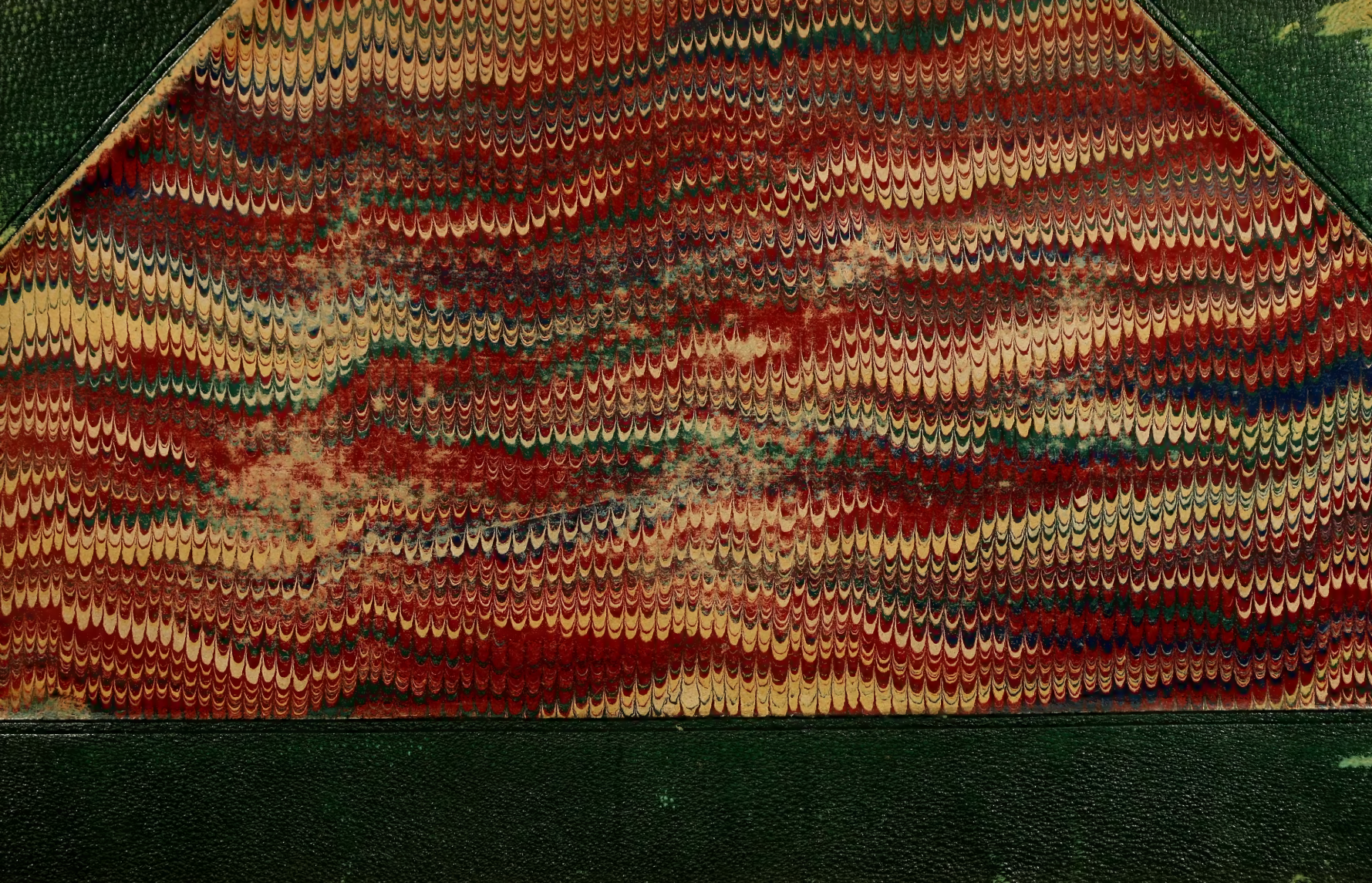

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CAPTAIN ERICSSON'S SOLAR ATTRACTION INSTRUMENT.

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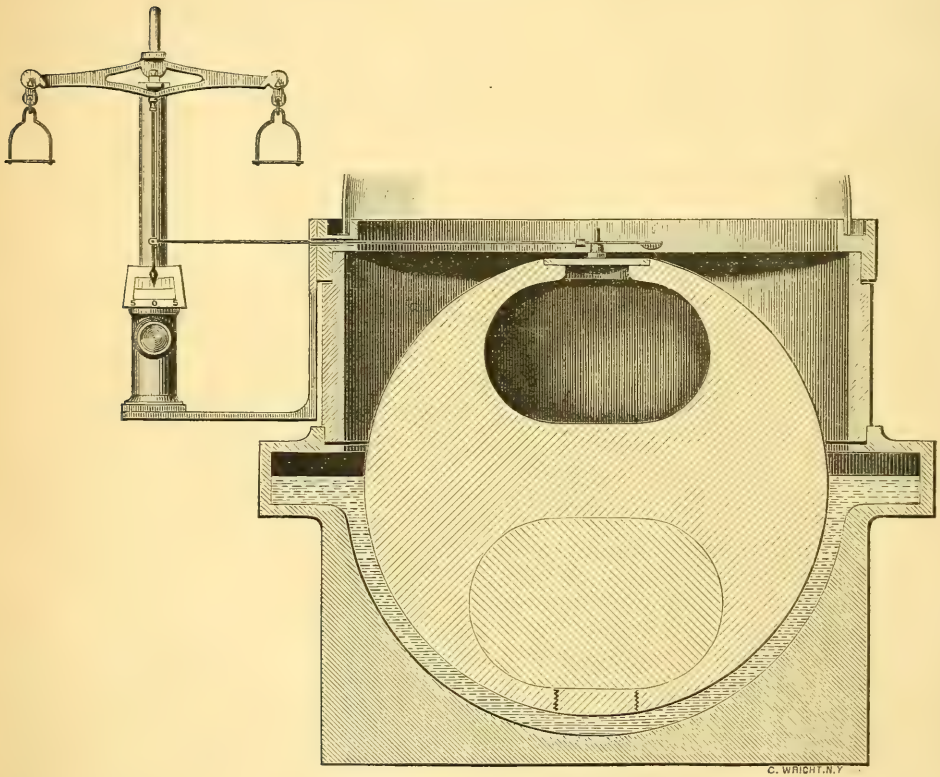

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SOLAR ATTRACTION AND THE EARTH'S ORBITAL CENTRIFUGAL FORCE.

By Captain JOHN ERICSSON.

The accompanying illustration represents an instrument constructed for the purpose of proving by actual practical test, that the sun's attractive energy is balanced by the centrifugal force called forth by the earth's orbital motion round the sun. I desire it to be distinctly understood, however, that my intention is not to demonstrate what astronomers proved centuries ago, namely, that solar attraction is counteracted by the centrifugal force resulting from the orbital motion of the earth round the luminary. Léon Foucault, in his celebrated experiment of swinging a pendulum from the dome of the Panthéon, in Paris, simply intended to furnish ocular proof of the correctness of the assumption that our planet rotates round an axis at right angles to the equator. So with regard to the instrument under consideration, the object is simply to furnish *ocular* proof of the correctness of the assumption that the sun's attractive energy is counteracted by the centrifugal force developed by the orbital motion of the earth round the sun. My scheme consists in presenting a highly polished iron globe floating on the surface of mercury, to the sun at the moment of rising or setting, the terrestrial attraction being then exerted at right angles to the line of solar attraction, hence incapable of interfering with its action. Repeated experiments conducted with the instrument at sunrise and sunset, have established the fact that although a tractive force of a few grains is capable of moving the polished iron globe over the surface of the mercury, yet no movement whatever takes place when it is subjected to the pull exerted by the attraction of the sun, as stated. A brief description will suffice to explain the nature of the device. The illustration represents a section through the centre of the iron globe and the circular cistern which contains the mercury. Two spheroidal cavities, it will be seen, are formed in the globe, the upper cavity being empty, while the lower one is filled with a metal of much greater specific gravity than iron, the object being to retain the vertical axis of the floating globe in a fixed position. A movable ring is applied at the upper part of the mercurial cistern, admitting of a free rotary motion, while the cistern remains stationary. To the said ring an angular bracket is secured, supporting the central column of a delicate chemical balance. Obviously this arrangement admits of the balance being turned in such a direction that it points towards the rising or setting sun without disturbing the mercurial cistern or its contents. The lower end of the vertical index of the scale-beam is connected with the floating iron globe by means of a straight steel wire, as shown in the illus-

tration. This wire, extending beyond the vertical axis of the globe, has a small counter weight applied at its extreme end in order to relieve the balance from disturbing influence. To prevent dust from lodging on the mercury, a glass shade covers the cistern, resting in a groove at the upper part of the rotating ring, the shade also preventing currents of air from agitating the sensitive globe during experiments.

Regarding the experiments which have been instituted with the new instrument, it will be proper to observe that, although the energy of lunar attraction is practically imperceptible, it has been deemed best to conduct the observations when the moon is in the first quarter, its attraction being then exerted at right angles to the line of solar pull. Let us now consider whether these observations have been conducted on a sufficiently large scale to warrant definite conclusions. The diameter of the iron globe being 11 in., and its weight 181.47 lbs. avoirdupois, calculations based on the relative mass of the sun and the earth and other known data, show that the pull resulting from solar attraction amounts to 748 grains. The fact that the floating globe, while subjected to such a considerable direct horizontall pull, remains stationaıy, while a tractive force of a few grains suffices to produce motion, at once suggests the following question: Is the surface of the mercury in the cistern perfectly level in a line pointing east and west—does not solar attraction raise the surface of the fluid metal at the eastern edge of the cistern, thereby producing an inclined plane which solar energy is incapable of causing the iron globe to mount? This important question the writer has disposed of by the following device: Two open cisterns containing mercury, connected by a horizontal tube, are placed 20 ft. apart on a level stone foundation. Above the centre of each cistern a micrometric mechanism is applied, by means of which the height of the mercury may be measured with the utmost precision The two cisterns, with their connecting tube, being placed east and west, and time allowed for the mercury to come to a state of perfect equilibrium, the micrometers are adjusted. This adjustment, it should be particularly observed, is made when the sun is in the zenith, at which time its attraction evidently cannot disturb the equilibrium of the fluid metal in the connected cisterns. The contact of the micrometers and the mercury is then examined from time to time during the diurnal revolution, the final observation being made when, near sunset, the two cisterns point towards the luminary, at which moment the attractive force tending to disturb the equilibrium of the fluid metal, is at its maximum.

Regarding the result of the observations conducted P. M., it may be briefly stated that, when the micrometers are properly adjusted, not the least excess of elevation of the level of the mercury in the western cistern is produced by solar attraction at the moment when the attractive energy is exerted in the direct line of the two cisterns. Persons familiar with cosmical questions will say, that in case the sun and moon should be nearly in conjunction when the observation is made, lunar attraction will sensibly affect the equilibrium of the mercury in the cisterns. The relative energy of terrestrial and lunar attraction at the earth's surface being in the mean ratio of 320,600 to 1, a difference of level in the cisterns amounting to 0.000748 of an inch takes place under the stated conditions. Consequently this difference calls for a correction, after the adjustment at noon, readily affected by turning one of the micrometer screws through an arc of 8 deg. 40 min., the pitch being 32 threads per inch. The perfectly level state of the mercury in the cistern of the solar attraction instrument having been established by such accurate means, the absence of any motion of the floating ball when subjected to the pull of the rising and setting sun, furnishes positive *ocular* demonstration of the fact, that the sun's attractive energy exerted on the mass of the iron globe, is exactly balanced by the centrifugal force resulting from its orbital motion round the luminary. No reflecting observer, aware of the actual amount of the solar pull (748 grains), can witness the perfect repose of the floating iron globe, on the level surface of the mercury, at the moment when the sun is rising, without being impressed with the importance of what he beholds. Again, if he has previously calculated the curvature of the orbit in which the instrument is moving, he can assert that the velocity of the floating iron globe round the sun must exceed 18 miles per second, in order to develop by centrifugal action an energy capable of counteracting the pull which he *knows* the globe is subjected to while he is watching its repose on the surface of the fluid metal.

MODERN LOCOMOTIVES.

From "The Engineer."

On the 11th of November 1873, Mr. John Robinson read a paper before the Institution of Civil Engineers "On Modern Locomotives." Mr. Robinson, with great propriety, and for reasons which are very obvious to those who are acquainted with the commercial position which he holds, contented himself with describing various types of locomotives, refraining almost altogether from criticising their various qualifications as exemplified by the economical result of their performances. The paper was followed by a very animated discussion, however, which extended over two evenings besides that on which the paper was read. The paper and discussion have now appeared in the published Transactions of the Institution of Civil Engineers, and will no doubt be read with interest by a large number of engineers concerned in the working of railways. The impression which we formed while the discussion was in progress is, however, unfortunately confirmed by a perusal of the statements of the speakers as now put before us in a complete form. Mr. Robinson said, with much justice, "*Quot homines, tot sententiæ*—as many engineers, so many engines." Most of the leading locomotive superintendents of the kingdom were present, and took part in the discussion, which resulted in this, that one locomotive is just as good as another, and better. In short, it appears that, not only is diverse work done with success by the same class of engines, but that engines of the most varied types are employed with equal success to do the same class of work. It is not difficult, however, for any one possessing experience in analyzing evidence, and practically acquainted with locomotive working, to reconcile some of the apparently incongruous arguments of the speakers; or to find a means of piecing together opposing assertions of fact. But after all has been done in this way that can be done, much remains to prove that either we have yet a great deal to learn concerning locomotive performance and train resistance, or that the modern locomotive is the most accommodating machine in existence, all sorts of work coming alike to it, without any regard to its type, and with very little regard to its size; while the cost of running and repairs seems to be decided more by the quality of material and workmanship used than by anything else.

Let us consider briefly what some of the arguments of the speakers lead to. We find Mr. Stirling, of the Great Northern, arguing that single engines, with 8 ft. drivers, keep better time, and burn less fuel, and cost less for repairs than coupled engines; and this, be it remembered, on what is really a heavy line, with plenty of inclines, worked at an excessive speed. On the other hand, Mr. Price Williams argued that for the Great Northern traffic a coupled engine must be superior to any single engine, and he was supported by other speakers. Again, we find that Mr. Fowler maintains that engines weighing not less than 43½ tons loaded could not work the Metropolitan traffic, while Mr. Webb, of Crewe, maintained that the work can be much better done by engines weighing but 32 tons; while Mr. Stroudley conducts a traffic quite as heavy, if not heavier than that of the Metropolitan Railway, at the same average speed—15 miles an hour—with engines weighing only 24 tons. Now, at first sight, it would appear that if any one of these gentlemen is right, the others must be wrong. Pursuing our examination, we find again that one engineer advocates the heating of the feed-water by the waste steam, and asserts that ten per cent. may be saved in fuel by such heating. But then another speaker tells us that he has been through the whole matter, and that there is no saving effected that is at all to be compared with the trouble and expense incurred. Again, we find the Le Chatelier brake extensively adopted by the Midland Company, while Mr. Webb states that he has tried it, and given it up because it cuts the cylinders. Then some engineers hold that brakes should be small, while others think they cannot be too large. These are but a very few of the points on which no two speakers could be found to agree; and, in a word, any engineering student who reads the paper and the discussion carefully will not know for some time afterwards whether he is on his head or his heels, and, if he is a youth of perspicacity, will infallibly come to the conclusion that locomotive designing is all a matter of rule of thumb, and that, as we have said, one engine is just as

good as another, and better. Let us see if this is really so, and endeavor to reconcile some of the conflicting arguments before us.

In the first place, it is evident, then, that a great deal that was said by each speaker has no more solid foundation in fact than the speaker's own opinion. A less logical discussion never, perhaps, was carried on by a body of scientific men. In the second place, we find a plentiful scarcity of statistical information. It would be too much to say that the paper and discussion possess little or no real value as sources of information; yet it is nearly the fact. It is by no means easy to analyze the results of the performance of any given type of engine, and draw correct conclusions from a comparison instituted between this type and some other; yet without such a comparison it is impossible to arrive at a just conclusion as concerns their relative merits. Nothing of the kind worth the name was attempted during the discussion under consideration—at all events, in the shape of logical reasoning. We can find no better example than that supplied by Mr. Fowler's statements. Put into a nutshell, his arguments are, that no better engines, except in a few points of detail, can be designed for working the traffic of the Metropolitan Railway than those in use. But he did not even attempt to prove that he was right. As a matter of fact, he does not know whether they are or are not the best. No doubt he thinks they are the best, in all honesty, because he designed them. But Mr. Fowler is not a locomotive superintendent, and he lacks the practical experience of such a man; and when we find Mr. Webb, who is a locomotive superintendent of great experience, asserting that Mr. Fowler is wrong, while Mr. Stroudley, another locomotive superintendent, proves that he is wrong by carrying as many passengers at as high a speed, over as bad a road, with engines little more than one-half as heavy as Mr. Fowler's, we cannot help rejecting Mr. Fowler's conclusions as unwarrantable. On the other hand, however, we must not condemn Mr. Fowler too hastily. It will be seen that those who took part in the discussion curiously enough confined their attention almost entirely to the number of passengers carried, and estimated the utility of their locomotives in terms of passengers only. Now the fact is, that both Mr. Fowler and his opponents in doing this, totally overlooked a most important factor in their calculations. We do not believe that one of Mr. Stroudley's little engines would work an ordinary Metropolitan train with punctuality. We are on the side of Mr. Webb and Mr. Stroudley, and opposed altogether to the system of working the Metropolitan Railway introduced by Mr. Fowler; but our objections are by no means confined to the engines, but to the entire stock, which is quite too heavy and unwieldy for the duty. Mr. Stroudley's success with his small engines is due entirely to the beautiful rolling stock which those engines haul—stock, in our opinion, admirably suited to its intended purpose, which the Metropolitan stock is not. Another example of the want of logical accuracy, manifesting, we might say, a total oblivion concerning facts passing daily around him, is found in Mr. Fowler's statement that "it would never do to have a rigid engine with six wheels coupled to pass round curves of ten chains radius, or seven and a half chains radius." "He believed that no engineer had ventured on such a desperate step to increase the adhesion, as to couple six wheels of the engine for a line with sharp curves." These two sentences prove directly either that Mr. Fowler really knows nothing at all about locomotives, or that in order to support his own opinions he thought proper to manifest what is really dense ignorance. To go no further, we may point out that the Semmering incline is worked by locomotives, some with 6 and some with 8 wheels coupled, and that on it are to be found plenty of curves with radii of 5, 6, and even $3\frac{1}{2}$ chains. In fact, no expedient is more common than the coupling of 6 wheels in the case of locomotives intended to work sharp curves. No one, so far as we are aware, ever proposed to work a rigid engine on such a line, except Mr. Fowler himself, who, if he would read a little more, would find that engineers are familiar with many devices for rendering engines as regards their wheel base flexible; as, for example, sliding axle boxes, the removal of flanges from driving wheels, and so on, all of which expedients are successfully in use.

The discussion gradually drifted away from metropolitan traffic to the relative merits of coupled and uncoupled engines. As regards the advocacy of the latter, Mr. Stirling stood almost alone; and as he represents a style of practice apparently rapidly becoming extinct, his observations de-

serve special attention. He stated that "he had constructed two classes of passenger engines, one class with 4 wheels, 6 ft. 6 in. in diameter, coupled; the other with a pair of 7 ft. driving wheels. Both engines had similar boilers, and cylinders 17 in. in diameter, with a length of stroke of 24 in.; the pressure of steam in the boilers was 140 lbs. On his frequent journeys from London, he had been in the habit of noting the size of the trains, and of the class of engine used. He found that with a similar train in both cases the single engine had fully the best of it, in fact generally beat the coupled engine in time to Potter's Bar, a distance of nearly 13 miles, and nearly all uphill, the gradients varying from 1 in 105 to 1 in 200. This led him to think that sufficient adhesion could be got with a single pair of driving wheels, and he believed no one would doubt the superior freedom and economy of a single engine over a coupled one. He then designed an engine,* the tractive power of which, by calculation, was 15 per cent. more than that of the coupled one, and in practice it performed proportionately more work. It conveyed trains of from 16 to 26 carriages from King's Cross, with ease, and on several occasions 28 had been taken and time kept. No doubt existed as to its running powers, a distance of 15 miles in twelve minutes having been accomplished with a train of 16 carriages. The engine had been perfectly satisfactory in all respects, and more of them were in course of construction. The average consumption of fuel, with an average load of 11 carriages, was 23 lbs. per mile. It might be said that a few pounds of fuel per mile was no great matter, but 1 lb. per mile on the Great Northern mileage per annum, represented a sum very little short of £5,000, and a few pounds would make up a large sum. The large engines were constantly employed on express trains, running from 45 to 50 miles an hour. It had been said the weight on the driving-wheels—15 tons—was excessive, and would be destructive to the permanent way; but such was not the fact as reported to him by the engineers of the line. The bogies in front carried a comparatively light load on each wheel, but quite sufficient to solidify the road before the driving wheels came on the rails, and thereby put it in the best position to carry the weight of the large wheels. The engines seem to have plenty of adhesion for the size and power of the cylinders, and did not slip more than coupled engines under similar circumstances; and, with a slight application of dry sand, slipping was entirely prevented. Powerful passenger engines were a necessity on the Great Northern Railway, from the undulating nature of the road, scarcely any part of the main line being level, and the ruling gradients were 1 in 200 throughout, except out of King's Cross, where there was a length of 1½ mile, with a gradient of 1 in 105."

Now these are beyond question remarkable facts, deserving some attention, and in a great degree borne out by the success with which single engines work passenger traffic on the London and North-Western and Great Western Railways. We need not say that the use of coupled engines is rapidly extending, and that Mr. Stirling is perhaps the only engineer to a first-class line of railway who maintains that single engines are right and coupled engines wrong. However, the fact remains that his engines do their work as well as coupled engines. Are we to assume, then, that single engines must be better than coupled engines? We think not. It is just one of the peculiar defects of this discussion, however, that almost the only argument urged against single engines was that they lacked adhesion; but this was just the point on which Mr. Stirling was strong, because he proved by citing daily experience that whether his engines had or had not as much adhesion as though they were coupled, it was certain that they had all the adhesion they needed for the performance of the duties required of them. Indeed, to argue that if they had four wheels coupled they would have more adhesion was about as much to the point as a statement that if the engine had 4 ft. instead of 8 ft. wheels it would be able to haul double the load.

It is impossible within the limits of a single article to even touch upon all the questions raised during this discussion, or to disentangle the mass of conflicting statements put before us. We shall return to the subject. Meanwhile, we may re-explain, to impress the facts on the minds of our younger readers especially, that much of the apparent inconsistency of the various speakers on metropolitan traffic disappears the moment we comprehend the fact that they spoke of engines and passengers only, with

* Complete working drawings will be found in our portfolio, Nos. 47 and 48, 1871.

little or no regard for the weight of the rolling stock used by each engine in hauling a given number of passengers; while, as regards coupled and single engines, the speakers once again spoke on abstract principles, with little regard for the special work to be performed by the engines. Thus, it would be easy to show that with two pairs of drivers coupled—the trailing pair carrying the weight previously on the trailing wheels of the engine, a considerable increase of adhesion and attractive force might be had; while if the bogie wheels were also coupled, the whole weight might be utilized for adhesion. If, however, no more adhesion is required than one pair of wheels will supply, it is useless to argue in this way, and the relative merits of coupled and single engines must be decided on a very different basis.

METHOD OF DEEP-SEA SOUNDING BY MEANS OF PIANO-FORTE WIRE.*

From "The Telegraphic Journal."

The great merit of wires compared with rope is the smallness of the area and the smoothness of the surface which the wire presents, as compared with the greatness of the surface and its roughness when rope is used with a comparable degree of strength. The wire that I have found suitable is piano-forte wire of the Birmingham gauge No. 22. It weighs about 14½ lbs. to the nautical mile, and bears from 230 lbs. to 240 lbs. pull without breaking. The quality of wire which I described to the meeting of the British Association at Brighton was special wire made for the purpose by Messrs. Johnson, the celebrated wire-makers at Manchester. They succeeded in producing a length of three miles in one piece of crucible steel, which certainly was a very great feat in the way of wire-making; and this wire was presented by them to me as capable of bearing a strain of about 230 lbs. I tested many specimens of it, and I found that none of them broke with a less strain than something like 220 lbs., and that many of them bore as much as 240 lbs. The wire then fulfilled all that the makers promised, and it had that quality which then seemed of paramount importance, a great length in one piece of metal. The truth is, that one of the impossibilities was splices. I tried splices in first experimenting in this process, and by making a twist of two pieces of wire together in a somewhat long lathe, and running solder all along the interstices, I made a very good splice. However, on testing this splice, I found that, although it would bear within 10 lbs. or 20 lbs. of the full weight of the wire, yet in every case of a pull with longitudinal force, the wire broke. This was precisely in accordance with theory. In fact, I always found that this was the case. The result never differs from theory; that is to say, the theory is correct. The sudden change of area of set between the long cylindrical wire and the thickening produced by the solder is an essential element of weakness. That is a general character which is well known to engineers. Inevitably, if the wire is of uniform character, it breaks close opposite the solder. To avoid this weakening of the wire, an exceedingly gradual commencement of the pressure or force by which one piece of wire is connected with the other must be attained. The obvious way of obtaining this is by a very long splice. A splice of 2 ft. long I have found quite sufficient. The splice I may describe shortly. The two pieces of wire to be spliced are laid, with one coinciding, approximately, 2 ft. with the other. At the middle of the lap, one wire being held out firmly, 1 ft. of the other wire is laid down with a very long spiral lathe. Then, turning to the other side, 1 ft. of the other wire is laid down in a lathe of the same quality. That is to say, there is a right-handed screw on each side. The wire has been previously coated with marine glue, just to increase a little the surface friction. The wires are found to cohere perfectly when splices are made in that way, all that is necessary to make the splice permanent being to cover the ends over for about an inch with a serving of twine just to keep the ends firm down. I have tested scores of splices made in this way; and in no one instance did the wire break in the splice or near to it. It always

*Read before the Society of Telegraph Engineers, by Sir Wm. Thomson, F. R. S.

broke some distance away, showing that the wire close to tho splice was as strong as the other part of the wire; and of course in the splice itself the two wires together give a greater strength than exists anywhere else. The difficulty with regard to splice being altogether got over, we are freer in our choice of the wire to be used; and, accordingly, upon the advice of Mr. Johnson himself, I went on sounding with piano-forte wire. Therefore I have been driven back to that, and I find that it is of much better quality than other wire. Mr. Johnson tells me that it is impossible to produce in other kinds the same quality of wire as is habitually made by the best makers of pianoforte wire. He said that although he could produce wire of great strength, he found it impossible to attain the same temper as that of the piano-forte wire. Acting upon his valuable advice with respect to the quality of wire, I have now begun to use altogether the best quality of piano-forte wire. That which I now adopt seems to fulfil all the qualities we look for in a material. The first difficulty, and one which seemed in the first place an insurmountable difficulty, was the tendency of the wire to kink and break. The first thing is to endeavor not to let the wire kink, and, in the second place, if by any accident it does kink, it is desirable that it should not break. I found that the piano-forte wire, if pulled to a breaking strain, would stand, without breaking, a far greater strain than it was exposed to in any part of the sounding process; and, therefore, we felt greater security that even a bad kink would not be liable to break. The lengths which another firm supply of this wire are, I believe, 400 yards. You must take that with some reserve, but to the best of my memory 400 yards is the greatest length. But, however, a splice at 400 yards or 200 fathoms is no inconvenience whatever. The defect in the original apparatus to be remedied is in respect to hauling in by the whim—this wire wheel which you see. It is in the same form that I have used all along. That is the original form of wheel, and the process of hauling is simply to coil it up. The wheel is about a fathom in circumference. My first sounding was in water of 2,700 fathoms, in the Bay of Biscay; 100 fathoms was the deepest sounding marked on the chart. I made a careful sounding, so that there is no doubt about the figures. I found, in hauling in by winding it upon the wheel, that, after about 1,500 fathoms had been taken in, the wheel began to show very serious signs of distress. The wheel was perfectly round and symmetrical at first, and when there was still about 800 fathoms out, it assumed very much the shape of an old sea cocked hat, and I had great difficulty in getting in the last 800 fathoms; and therefore, of course, the wheel and the work were not perfectly related to one another. I have made various attempts to overcome the difficulty. My first attempt issued in failure. It consisted in stopping the process after a certain number of fathoms, say 20 fathoms, taking the strain off the wire, and easing it round the wheel. It was done in a sounding of 1,200 fathoms, made in Funchal Bay, Madeira, only a few miles from Funchal, during Hooper's cable expedition to Brazil last summer. I found that the process was, in the first place, exceedingly tedious. I found that stopping every 20 fathoms did not seem to be of any use at all, so I stopped at 10 fathoms, and it made a very long job in 1,200 fathoms, and besides, it did not afford sufficient accuracy. That plan being a failure, I then looked out for some other; and the peculiarity of the present apparatus consists in the way in which that difficulty was overcome. I may say that in the American navy another mode of getting over it has been followed. The wheel has been strengthened and the weight has been detached in the American soundings by wire. One of the trigger detaching apparatus has been used, and the weight has been reduced. That, of course, lightens the pull upon the wire very greatly. By those means—the strengthening of the wheel and the lightening of the pull—the Americans got over the difficulty very well. I, however, did not consider it desirable to throw away 30 lbs. or 35 lbs. of lead or iron at every sounding, and we found it well to do all we could, in moderate depths of 3,000 fathoms, to bring back the sinker; and if we got into the way of doing that in 3,000 fathoms, then we might be able to do it in greater depths. The Challenger failed in this respect, in taking soundings in the Gulf Stream; but by this process that which baffled the Challenger is made very easy. And there are greater depths, no doubt, than any which we have found. Perhaps we may have got near to the greatest depths. The Challenger has shown us 3,500 fathoms, but I think that it would be

rash to say that there are not depths of 5,000 fathoms. I should wish, therefore, to do all we can without throwing away our sinkers in depths of 3,000 fathoms. In the case of very great depths, we might, perhaps, take a heavier sinker and detach it. In the meantime we have no difficulty in recovering the sinker from a depth of 3,000 fathoms; and, having no difficulty, I prefer an apparatus which will in every case bring back the sinker. I will explain the method of doing away with the defect arising from the strain of the wire, experienced through having a heavy length of wire coiled up on the wheel, and a heavy pull. In the first place I shall describe the process of sounding from a ship hove to for the purpose of making the sounding, and I shall say a word or two in conclusion about flying soundings—soundings made without stopping the ship—which are of great importance in cable expeditions. But, in the first place, with regard to soundings when the ship is hove to, the sounding being the great object. Of course the ship is kept, as nearly as may be, at rest, and that is continued as long as is necessary for bringing up the wire and the sinker. The weight is attached by a piece of rope to a ring or clamp, the ring or clamp being attached to the wire. That is a first precaution which I introduced to avoid kinking. No matter how carefully the operation may be conducted, we never can be quite sure but that a little line will be allowed to run out after the weight reaches the bottom. If the wire was attached direct to the weight, the moment the weight reached the bottom there would be kinking; and that was one of the great difficulties. I have been told in our hydrographic department, "You need not try sounding by wire, for it is impossible! The wire goes over the rope, and the moment you try to pull it up it kinks." Therefore, instead of allowing the wire to become slack, in my first experiment I attached the weight to the clamp by 15 fathoms of cod line, and that clamp was attached to the wire. The clamp was about 4 lbs. weight. At present, in the apparatus now before you, there is a ring, weighing, perhaps $\frac{1}{4}$ lb., attached direct to the wire, but I believe that it will be advisable to add weight to that ring, because I think there may be some little risk of the wire becoming slack when the weight comes to the bottom, and I should not like to trust to the wire shooting through the water with no more weight than that upon it to keep it tight. Therefore I propose to add weight to the ring, so as to bring it up to 3 lbs. or 4 lbs. Well, now, of course everything depends upon the stopping when the weight comes to the bottom, because if you do not accomplish that, then the bugbear of the wire coiling on the bottom, and kinking when you draw it up, will be a reality. The mode by which I secured that there shall be very little more line paid out from the ship after the weight reaches the bottom, is simply this: A measured resistance is applied systematically to the wheel, which resistance is always to be more than enough to balance the weight of the wire out. Suppose, for example, we apply a resistance exceeding by 10 lbs. the weight of the wire out. The sinker which I have used is 30 lbs., the clamp 4 lbs. We have, then, 34 lbs. between the clamp and sinker. There is the resistance of 10 lbs. exceeding the weight of the wire out, and thus we have 10 lbs. off the 34 lbs. of the sinker and clamp. That is, we have 24 lbs. weight for the moving force. That, I have found, is amply sufficient to give a very rapid descent, a descent so rapid that certainly in the course of half an hour, or three quarters of an hour, the bottom would be reached even at a depth of 2,000 or 3,000 fathoms. Then, of course, there must be great care in paying out the wire. The person in charge must watch. We have a counter here for the time. You cannot see it, for it is on the far side, but I dare say that every member of the Society of Telegraph Engineers can imagine a counter for counting the time. The person in charge watches the counter, and for every 250 fathoms (that is, every 250 turns of the counter), he adds 3 lbs. to the break. That makes 12 lbs. added to the break, or to the resistance, for every 1,000 fathoms. The weight of 1,000 fathoms of the wire in the air is $14\frac{1}{2}$ lbs. In water, therefore, the weight is about 12 lbs.; so that if the weight is added at the rate I have indicated, the rule stated will be followed. That is to say, you commence with a certain weight, and you keep adding to it as the wire goes out. Well, when the weight suddenly reaches the bottom, instead of there being a pull, or a moving force, of 24 lbs. on the wire tending to draw it through the water, there will suddenly come to be a resistance of 10 lbs. against its motion. A few turns of the wheel, two or three at

the most, suffice, and the motion is stopped; and, therefore, long before the clamp gets to the bottom, if we have 10 fathoms of line between the weight and the clamp, the wheel stops. The instantaneous perception of the bottom, when this rule is followed, is very remarkable. In the American process they describe the result as being most satisfactory. In their case, the wheel simply stops when the weight comes to the bottom; and they will detach, as I have said, and begin the hauling in direct on the wheel. My process differs from the American process in the mode of hauling in the wire again. [Sir W. Thomson demonstrated the method of hauling in by means of his wire-sounding apparatus.] We suppose the bottom to have been reached. In a moment the wire wheel is run back, and the wire gets upon the pulley. Observe, it has been paid straight down into the sea. We have a spun yarn stopper, which is put on in the usual way. In fact, two men with thick leather gloves can stop the wire by their hands, but the stopper is so quickly put on that I prefer it. The wire is then held by the stopper, the strain is taken off, and the weight is held by the wire. We then just cary the wire over the top of this wheel. If the depth be anything under 3,000 fathoms, I should say one line round is quite enough. For 4,000 fathoms I would take it twice over the wheel. It will work well enough when taken over twice, but a little more care is necessary. The stopper is now ready to go, and we haul in. The hauling in is conducted on just the ordinary sailor's plan, and the slack is taken off round a drum. By this process we can, by a few turns, relieve nine-tenths of the weight as it is coiled on the wheel. With one turn we can very readily take off three-quarters of the stress. I need not go more into detail as to process for accelerating the matter. I may just say that there are plenty of men available. Instead of handles I put on a pulley with a sharp V groove, one on each side; and then, with a snatch block, and with a deck 10 fathoms in board, the wire can be hauled tight; and three men hauling on one side, and three on the other, can get this up at a very rapid rate. By multiplying the speed in that way, there is no difficulty in hauling in at the rate of about 8 nautical miles an hour, so that the hauling in from a depth of 3,000 fathoms will be done in about 25 minutes at the utmost when proper arrangements are made. Of course, if there is a very heavy sea, augmenting considerably the stress above the mean stress, then slower hauling in will be practised. A little arrangement will be made by which the men can haul in as fast as they please, and be unable to put on more than a certain force. There will be the benefit of speed. It will come in fast when the strain is easy, and not come in at all when the ship is riding and would break the wire. That arrangement is exceedingly easy when we use the handles in the way that I suggest. The advantages of this process, I think, are very obvious. You see the simplicity of the apparatus, and the comparative inexpensiveness of it. No donkey-engine; no three or four hundred pounds of iron cast away every time, and so on, as in the ordinary soundings; and withal there is a very much surer sounding than the ordinary process can give at the same depths. And, lastly, there is the possibility of effecting a sounding in cases in which, as in the case of the Challenger in the Gulf Stream, the most mature previous process fails altogether. I think it highly desirable that this process should be taken up by our own Admiralty. There is a great tendency to the other side. I have a semi-official letter to the effect—"When you have your apparatus perfected, we may be ready to try it." I may say that it seems a little strange that after my having intimated, in the month of June, 1871, the perfect success of wire for sounding in depths of 2,700 fathoms, the Challenger was allowed to go to sea without taking advantage of this process, and that a year and a half later I should be told—"When you have perfected your instrument, we will give it a trial." The American navy looked upon the matter with different eyes, and certainly in a different spirit. They moved those who had the direction, and they took it up with the very greatest zeal. They found my apparatus full of defects, but they never asked me to perfect it, but they perfected it in their own way, and obtained results. I went on independently in another line, and made a considerably different apparatus from that which is now being used by the Americans; but I certainly was very much struck by the great zeal and the great ability which the American naval officers showed in taking up a thing of this description, which had once been proved to be good, and charging themselves with im-

proving the details, and making it a workable process. If I may be allowed two or three minutes longer, I will describe the method of making flying soundings with wire. In the first Hooper expedition, from Pernambuco to Para, the Brazilian Government sent a gunboat with us to take soundings, but the coal would not carry her the whole way, and we were left to our own resources for soundings during the laying of the cable. The whole route had been sounded over previously by the Brazilian Telegraph Company, so as to form a general idea of the line to be taken by the cable; but still it was very important that soundings should be taken accurately. Accordingly, Captain Headingley arranged that the wire wheel should be set up over the stern of the Hooper, and soundings were taken every two hours without stopping the ship. A 30 lb. weight was hung on a couple of fathoms of cord; but a greater length would have been better. I believe that 5 fathoms ought to have been used. Then the wheel was simply let go, with a resistance of about 8 lbs., or, perhaps, an actual resistance of not more than 6 lbs. on the circumference of the wheel. When the ship was running at the rate of $4\frac{1}{2}$ knots an hour, the cable was paying out at the rate of 6 knots; and after, perhaps, 150 fathoms had run out—in some cases 175 fathoms—suddenly the wheel would get so much slower that it almost stopped. In half a turn it was obvious that there was a difference. The moment that difference was perceived, the man standing by laid hold of the rim of the wheel and stopped it. Thus they achieved flying soundings in depths of 150 fathoms with the ship going at the rate of 6 miles; and they obtained information of the greatest possible value with reference to the depth of the water and the course to be followed by the cable. I think this is of such great importance, that I never would like to go to lay a cable without an apparatus for flying soundings to be regularly practised, say every two hours at the least. The warning that this practice gives of shallow water, or of too great a depth of water, has a value which, I think, the members of the Society of Telegraph Engineers will readily appreciate. There is one point which I omitted to refer to, and that is the arrangement of the stern pulley. It is arranged so that if the ship is making a good deal of lee way, the wire may still be hauled in. Supposing the ship is drifting, and making lee way, instead of being at right angles, we can haul just as well. The wheel turns on a horizontal axis, and there is no strain on the wire at all. A very moderate amount of drifting, especially in a sailing vessel, may produce a great alteration in the angle, but it makes no difference to the hauling of the wire. The wheel turns readily round either way, and even during the rolling of the ship you can keep the wire on the wheel. I tested it with a wire like this on the steam launch Hooper, and the wheel accommodated it to every quick movement of the vessel. There is one interesting topic in connection with this plan of using wire, and that is the sound produced by the wire. All the time we are employing piano-forte wire in this way, we have a "sounding" in a double sense. There is always a vibration going on, and there is this use which we may make of the sounding quality of the wire. By putting a stop in a given position on the wire, we can estimate the strain on the wire with great accuracy. If you stand by the wire and give it a little blow, a good musical ear can tell within 10 lbs. what the strain is, simply by the sound.

Mr. Froude said that he had the pleasure of seeing the first specimen of sounding wire which Sir William Thomson had made, before it was used. He forgot whether at that time Sir William Thomson had hit upon his extremely ingenious and nice mode of taking the strain off the wheel; but one could see at once that it was perfectly easy and must succeed. The idea of making a strong joining in the wire by a long succession of weak fastenings, seemed a very instructive mode of getting over a serious difficulty. He saw from the beginning that the joints might be put together by solder; but it was obvious to him that the stiffening of the wire by the solder must have a bad effect. He thought that it was much to be regretted that the Admiralty did not at once take up Sir William Thomson's process. They were much more disposed to take up such things than they used to be; and he was rather surprised, knowing how high Sir William Thomson's authority stood, that they should have any hesitation in taking up the process. He (Mr. Froude) wished to ask how the difficulty of corrosion by salt water was ultimately overcome. The use of oil had been under discussion.

Sir William Thomson said that there

were two methods of guarding against rust. The Americans used oil by submerging the wheel in oil when it was out of use. Commander Becknack having carried out the process of wire sounding with remarkable success, he (Sir William) supposed that the Americans were satisfied with the preserving power of the oil thus used. On board the Hooper the deep sea sounding wire was preserved by caustic soda when out of use. That substance, when bought wholesale, was so inexpensive that the cost of that mode of keeping the wire from corrosion was not worth speaking of. There was, however, a good deal of trouble connected with it; but it must be remembered that that trouble would not be regarded on board a ship appointed specially for making soundings. The preserving effect of alkali upon steel was well known to chemists. It seemed to be due to the alkali utilizing the carbonic acid in water, for the presence of carbonic acid in water was the great cause of iron being corroded. The fact was well established that iron would remain perfectly bright in sea-water rendered alkaline by a little quick-lime. Caustic soda was a more sure material, because we could make more certain that the water was really alkaline. He was told by a very excellent authority, Mr. James Young, the chemist, that whether caustic soda or quick-lime was used, all that was necessary in order to make sure that the pickle would be a thorough preserver of the wire was, that it should be found to be alkaline when tested with the ordinary litmus test-paper. The American experience was, that although the caustic soda preserved the wire, it ate away the solder, and on that account the Americans adopted the use of oil. Oil seemed objectionable on account of the mess and slipperiness which it would cause if it got scattered about the deck; and yet the Americans seemed to manage to work with it very well.

Mr. Matthew Gray said that sixteen months ago he had occasion to lay a cable across the Bay of Biscay, and previously to that time, though he had never heard of what Sir William Thomson had done, he got an apparatus made very much like the upper portion of that which was now exhibited. In going to sea with it, they found no difficulty in taking the soundings in 1,300 fathoms. He was not so fortunate as Sir William was, in getting good wire of sufficient strength to pull up the weight, and the wire was broken two or three times. At last they constructed a weight which got left at the bottom when it touched the bottom, and with that they were pretty successful. They used oil for keeping the wire from rusting. The oil was kept in a trough, and a flat india-rubber bearing, rubbed against the wire to rub off the superfluous oil, and keep it from flying over the deck. That seemed to answer the purpose very well. He might mention that he also made an apparatus with a view to picking up a larger portion of the bottom than is usually done. It was shaped something like a sugar-tongs, but the jaws were not fitted with sufficient accuracy, and the water washed out the material which the tongs took up. He had no doubt that in all cable-laying in the future, much would be done by the apparatus which Sir William Thomson had constructed.

Captain Hull said that in his surveying experience he had had very little to do with deep sea soundings, but, in consequence of what he had heard that night, if he was sent to perform deep soundings, he should apply for his ship to be fitted with such an apparatus as Sir William Thomson had described. He (Captain Hull) thought that some modification might be made in the mode of taking flying soundings by the use of an old-fashioned implement used by sailors. It was a kind of floating pulley connected with a little canvas bag, which would indicate when the bottom was reached by acting in the reverse way to a float such as is used in ordinary fishing.

Mr. Matthew Gray said that he should like to know how it was that Sir William Thomson's pulley was so much injured by the weight of the wire, and why it would not do for the wire to drop up direct from the pulley. He (Mr. Gray) did not find any difficulty arising from that cause. Perhaps Sir William Thomson would say whether he brought up anything from the bottom, and if so, how he did it.

Mr. Latimer Clark asked how the friction strain on the wheel was regulated and adjusted, and also whether the sinker was recovered in flying soundings.

Professor Clerk Maxwell asked whether cross-filing of the wires at a splice for increasing the grip would do so much harm by weakening the wires as to outbalance the advantage of the increased hold.

Sir William Thomson, in reply, said that cross-filing to prevent slipping would in-

jure a wire by taking away its strength, more than it would help in increasing the friction. Marine glue was found to answer so well that he did not think that any process of roughening was necessary. For regulating the resistance, he used a form of brake which he patented in the year 1858, and he had used it in his own laboratory ever since, though it had not come into general use. It had answered very well, and he believed that it might be used with advantage in paying out a cable, although there were difficulties in the case of a cable which could not be rashly dealt with. Besides the groove which carried the wire, there was a groove with a semi-circular section, into which the rope was placed one turn and a quarter round the wheel. The end of the rope was secured to a pivot. [The use of the brake was demonstrated.] The question of regulating the resistance might be answered in this way. The difference of tension of the cord at the heavy tension end, where the weights were attached, and the light tension end, was equal to the resistance. He had used a spring balance at one end. The method was to note what a spring balance was standing at, and then subtract it from the weight. That would show what force was on. He had another appliance. It consisted of simply casting off the cord and putting on a hook over the rim of the wheel. This was carried over the pulleys, and with a cleet was hauled off on a spring balance. The spring balance would weigh with the greatest accuracy the stress upon the wire. With regard to Captain Hull's suggestion as to the use of the canvas float in flying soundings, no doubt it would increase the accuracy of the sounding, but it would induce some degree of complexity, which must be avoided. As to the recovery of the weight, he might say that they always accomplished it, and they never lost a pound of lead if they could help it. His process was in this respect a great contrast to the ordinary method. Six men would be required to bring up the ordinary heavy sinker. There was also a great saving of time as compared with the ordinary method. At 2,000 fathoms, the wire would take not more than ten minutes to run down. A 30 lb. sinker might be hauled after a depth of two miles in fifteen minutes. In fact, twenty minutes could be made sufficient for a 2,500 fathom sounding when the object was to perform the sounding in the shortest possible time. The flying soundings of which he had spoken were only approximately correct; but they were useful as guides in the laying of a cable, and a little experience would enable the observer to make such an allowance as would give the accurate depth. Mr. Gray had put a question about specimens of the bottom. He (Sir William Thomson) had obtained specimens of the bottom by means of a butterfly valve of the ordinary pattern. Mr. White had made an improvement on the butterfly valve, and many other improvements had been made upon it.

The Chairman expressed the thanks of the Society to Sir William Thomson for his interesting communication. Like most other mechanical arrangements, the method which had been described was not absolutely new, and he (the Chairman) was not surprised to hear that attempts had been made to sound by means of wire instead of line; but the merit of the present apparatus, as well as of any other well-advised mechanical arrangement, consisted of the appliances to make the result a perfect one, and in that respect the apparatus would commend itself without any words from him.

There were many difficulties which presented themselves at first sight against the use of wire for soundings, but they were met in the most perfect and ingenious manner. First of all, to get wire of such uniform strength as to reach to a depth of three miles required very considerable attention. Nevertheless, piano-forte wire offered extraordinary strength and a certain degree of toughness, and was, therefore, a very inviting material; but how to join the wires in such a manner as to be thoroughly reliable was a matter requiring very mature consideration, and this difficulty had been met in the most perfect manner. Then the mode of checking the motion of the drum by a single rope, though in itself involving only a pony brake, was a very ingenious adaptation of means to the particular end, and it was brought in usefully for telling in the most absolute manner when the weight struck the bottom. There were other points of great ingenuity about the machine, and he had not the least doubt with regard to its practical value in making deep-sea soundings by wire. He had himself made deep-sea soundings some years ago, and he knew that for a depth of 2,000 or 2,400 fathoms they always took up the best part of the day, or at least some four or five

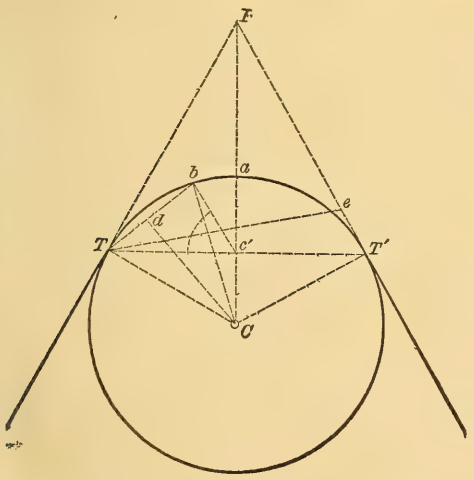
hours, and it was a very difficult matter sometimes to keep the stern of the ship over the line. The latter friction of the line in the water was so great that the load would not follow, and therefore the ship had to be manœuvred so as to keep over the line. The wire apparatus, instead of occupying five hours, accomplished a complete deep-sea sounding in thirty-five minutes. That was a matter of really the highest importance, especially in making the soundings for a submarine line, where time was sometimes a very great object. The flying soundings were also matters of great interest. If they could be accomplished with any degree of certainty with this apparatus, it would be a great achievement. For his own part, he had sent out the apparatus with every ship which he had lately had to fit for sea.

LAYING OUT CURVES OF SMALL RADIUS.

By G. H. MANN, C. E.

Written for Van Nostrand's Magazine.

The method of laying out railroad curves by deflection is often inconvenient, when the radius is small, as the chords must be taken very short and are frequently inconveniently close to the instrument; the method by perpendiculars to the chords requires too much changing of the instrument, and is deficient in economy of time. The



writer has employed the following method to advantage, when the point of intersection was not accessible and the radius small.

The random line T *e* is first run, and the angle I found by measuring I *e* T and I T *e*, and taking their sum from 180°. Then I T T′ determined, and the chord T T′ located. On this middle point, *c′* is taken as the station. Then, if we lay off any line *c′ b*, making an angle I with the chord, the distance on this line to the circle will be

$$d = b\,c' = \sqrt{R^2 - h^2\cos^2 I} - h\sin I. \qquad (1.)$$

R = radius of circle $= \frac{\frac{1}{2}\text{ chord}}{\sin \text{I T T}'}$, or $\frac{\text{T } c'}{2\sin \text{I T T}'}$;

$$h = c'\,C = \tfrac{1}{2}\text{ chord} \times \tan \text{I T T}';$$
$$\text{or T } c' \times \tan \text{I T T}'.$$

This value (1) may be determined as follows:

$$x^2 + y^2 = R^2. \qquad . \qquad . \qquad (2.)$$
$$x = d\cos I,\ y = d\sin I + h.$$

(2) becomes

$$d^2\cos^2 I + d^2\sin^2 I + h^2 + 2\,d\,h\sin I = R^2.$$
$$d^2 + 2\,d\,h\sin I = R^2 - h^2.$$
$$d + h\sin I = \sqrt{R^2 - h^2 + h^2\sin^2 I}.$$
$$d = \sqrt{R^2 - h^2\cos^2 I} - h\sin I.$$

Or we may, if stakes are to be set at equal distances along the curve, proceed as follows:

Let T b = V ∠ T c b = a, b T c' = β.

Then $a° = \frac{l}{2\,\pi\,R} \times 360°$, and

$\frac{1}{2}\,a° = \angle$ T c d or b T I $= \frac{l}{\pi\,R} \times 90° =$

$\frac{l}{R} \times 28° 39'$; then

$$\beta = \text{I T T}' - \tfrac{1}{2}a.\ d^2 = \overline{\text{T } c'}^2 + \overline{\text{T } b}^2 - 2\,\text{T } c\,\text{T } b\cos\beta,$$

or if c = chord, $d = \sqrt{\frac{1}{4}c^2 + l^2 - c\,b\cos\beta}$:

and angle I is found thus:

$$\sin I = \frac{l\sin\beta}{d}.$$

It will be noticed that the exact length of each arc is laid out, and no error arises from the chord being taken equal to the arc. For curves of small radius, and where the length of arc is required to be quite small, this method has the advantage that the instrumental work can be done very rapidly.

IRON AND STEEL.

From the "London Mining Journal."

The only sure and certain path to perfection in any branch of manufacture is undoubtedly that of painstaking research and analysis. By this means the basis and principle of any successful operation is distinctly pointed out and noted, and the causes of failure observed for future avoidance. Thus every failure and every success alike become steps to increased knowledge and better success for the future. If there is any one branch of manufacture that we pride ourselves upon, it is surely that of the working and production of marketable iron and steel.

We should not, however, from our practical successes conclude that we have nothing further to learn in this branch of manufacture. And we should further give careful heed to the results which any painstaking investigator or analyst may publish to the world, since we can never say but that some as yet undeveloped germ of truth may therein lie hid ready to the hands of the enterprising practical man for production as a great commercial success. With these few words of preface we feel sure that our readers will give careful heed to the results of some most painstaking and exhaustive investigations in iron ores and steel by an eminent French metallurgist and chemist, M. Fremy.

He states in order the important facts at which he has arrived, some of which we think will be rather subversive of the established ideas and prejudices of the iron and steel producers at large.

1. He declares that there are no ores distinctly differing from iron ores as suitable for the production of steel. All good iron ores will produce good steel if they do not contain any minerals unsuitable to the production of steel.

2. The steely character of some ores is due simply to the purity of the iron, and not to any peculiar property of any special ore. In fact, the suitability of an ore to the production of steel depends on good metallurgical work rather than on any special quality of the ore.

3. Carbon is undoubtedly the essential element in producing good steel and good castings from ore. But it is not the only body which may be in true chemical alliance with the iron, as for instance the silicium in the Bessemer castings, or the manganese in spiegeleisen.

4. The bodies which will combine with iron are numerous, and they will by their combination produce an infinite variety of results.

5. The irons of commerce, the steels and the various pigs, should then be considered as alloys of iron, in which varying quantities, often of minute amount, of different compounds, primarily carbon, then sulphur, phosphorus, and arsenic, produce definite qualities of material.

6. It is a well-known fact, that commercial iron is far from pure iron, or even from a simple compound of iron and carbon. The qualities of the various brands are modified by sometimes extremely minute quantities of foreign substances. The various brands and varieties of iron should be considered as the most important alloys that iron can form with other elements. These agents modify the iron depending directly on their nature and proportion. Some harden the metal and give it great resistance to shearing; while others, on the contrary, raise its tenacity, and cause it to lose others of its qualities. The present classification of iron is undoubtedly sadly deficient. The best and most precise terms are simply founded on an incomplete recognition of their physical characters. The day will surely come when all varieties of iron shall, as in other mercantile substances and alloys, be known by chemical analysis, and produced as exact compositions, the definite physical nature being an absolute necessity thereupon. This plan has already been to some little extent adopted in one or two places on the Continent, and has given great satisfaction.

7. There are two great heads or divisions in what we term wrought iron. These are fibrous iron and crystalline iron. The crystalline iron is usually the result of the combination of a minute quantity of carbon with the iron. This may be considered to be always the case where the crystallization is natural and stable. An abnormal crystallization is, however, often produced by sudden chilling, or, it is said, by continued hammering; but this abnormal crystallization can be always removed by annealing.

8. The third modification of iron with alloys, but principally with carbon, is that of the family of mild steels. It is difficult to draw a line between crystalline iron and mild steel; however, the grain of mild steel is brilliant, generally very fine, and cannot very well, when compared, be confounded with that of crystalline iron. Soft steels should be considered as alloys of iron and carbon only, with an exception in favor of manganese. All other substances spoil its quality.

9. The fourth modification of iron comprises the numerous families of brittle and hard steels. These steels are produced by the combination of iron with a considerable portion of carbon, and also by the combination of other bodies, of which the hardening effect is added to that of carbon. It should be particularly noted in the manufacture of steel that if the presence of some bodies are beneficial to the combination of carbon and iron to produce steel, there are other very injurious substances, such as sulphur and phosphorus, which act as deterrents, preventing the easy combination of carbon and iron. These should be removed with as much care as an acid or alkali preventing a wished-for precipitate would be from a chemical solution.

10. The fifth modification produced by the combination of a still greater excess of carbon, both chemically and mechanically mixed, and also with other various bodies, is the variety of cast irons, varying through soft, hard, tough, brittle, grey, or white. Although this form of iron is usually the first obtained from the ore, it holds, as a chemical alloy, a position further removed from pure iron than steel. It was the full appreciation of the chemical order of cast iron, steel, and then wrought iron, that originated the Bessemer simplicity of production of steel from cast iron, instead of from the purer wrought iron.

All the foregoing facts may be, and probably are, well known to any who may have made iron and steel their business or study; but we think that the possibility of accurate chemical classification of all varieties of commercial iron, is an idea as yet not generally received or understood. We firmly believe that such a classification will be a fact in the near future, and that the uniformity of various classes and brands of iron will be thus greatly enhanced.

ILLUMINATING BY THE MAGNETO-ELECTRIC LIGHT.

From "The English Mechanic and World of Science."

In our last volume it was stated that a Mr. Ladiguin, of St. Petersburg, had succeeded in removing some of the defects connected with the utilization of the magneto-electric light for purposes of illumination. Some experiments with this method were carried out recently at the works of Messrs. Warner, in the Euston road, in the presence of Sir C. Wheatstone, Mr. Sabine, Col. Stuart Wortley, and many other scientific men. M. Lodyghin (as it appears his name is spelt) has invented a system by which an electric current can be subdivided and so made to produce a number of lights. The subdivision of the electric current as it flows from the generator has before been attempted, but the fine carbon points were quickly consumed when burnt in contact with oxygen. Thin platinum wires have also been tried, but as soon as they commenced to give a perfect light they were melted. It occurred to M. Lodyghin that the difficulty might be overcome by using a vacuum, and so burning the carbon out of contact with the oxygen of the atmosphere. Metallic connections, however, had to be used, and as the metal and the carbon expanded in different ratios, the carbon was subject to fracture. The metal, moreover, melted at the points of contact with the carbon, and so the question remained practically unsolved. M. Lodyghin's idea was then taken up by M. S. A. Kosloff, who, after many months of experimental research last year in Paris, at length succeeded in overcoming all difficulties, and in producing a practical and efficient means of subdividing the electric light. M. Kosloff has invented a special metallic alloy of which he forms the holders for the carbon points (or rods, as they are more properly termed), and these are placed in a glass vacuum chamber or lamp. The lamps which were experimented with were nine in number, six of them having two carbon rods, either of which could be placed in connection with

the current of electricity. The rods were all 18 millimetres in length, and one in each lamp was 2 millimetres in thickness, the others being $1\frac{3}{4}$ millimetres thick. The other three lamps contained each a carbon rod 70 millimetres in length, 2 millimetres thick, and also connected with the main current.

The first experiment consisted in burning a carbon rod in contact with the atmosphere, the rod being consumed in a few minutes. The current was then turned on to the thicker rod in each of the six lamps, and a brilliant but not overpowering light was produced, which improved as the current was increased in intensity. The reason for lighting the thicker rod first was that it might consume the oxygen in the lamp, by which the rod was reduced a quarter of a millimetre, and was thus brought down to the gauge of the second rod. The current was then directed through the second rod with equally satisfactory results in all the six lamps. The three lamps with the longer carbon rods were then lighted and successfully exhibited, changes being frequently made from the six to the three lamps and back again. The apparatus used for producing the current was Gramme's magneto-electric machine, which was illustrated and described on p. 557, Vol. XIII., and which produces a fine continuous light. With the Gramme machine running at about 200 revolutions per minute a moderate light was obtained, which was greatly improved at 300 revolutions, the maximum of intensity being obtained at 450 revolutions. The strength of the light depends upon three things—the power of the machine and the number of its revolutions, on the length and thickness of the carbon rods, and on the quality of the carbon. The experiments showed that with the same strength of current and the same number of revolutions, double the amount of light was obtained with the three long carbon rods as compared with the six short ones.

The experiments demonstrated satisfactorily the fact that the electric current could be subdivided, and hence, if practice confirms experiment—which it is believed it will—there is a wide field open for the application of Kosloff's system. And it should be here remarked that the form of lamp used by the inventor is also experimental, and its variation does not affect the principle. He leaves it to mechanical science to devise a lamp which shall meet the varied requirements of lighthouses, mines, submarine works, railways, and other purposes, to which, it was the general opinion of those present at the experimental trial, the principle is thoroughly applicable.

The Next Largest Steamer Afloat.—On the 6th ult. Messrs. J. Elder & Co., of Glasgow launched a vessel for the Pacific Steam Navigation Company. She is 460 ft. long by 45 ft. wide, and 37 ft. 6 in. deep, and is of 4,820 tons, gross. This makes the sixth vessel which this firm, which is the leading one on the Clyde, have launched for the same company. The steamer is to be fitted with compound engines of 650 horse power nominal, will be bark-rigged, and will have iron masts; and for the convenience of loading and discharging cargo, 5 powerful steam winches have been fitted up. She has capacity for 4,500 tons measurement, exclusive of 900 tons of coal. The ship is divided into 8 water-tight compartments, and has 8 small boats, one of which is a steam launch. She will have accomodation for 140 first-class, 50 second-class, and 800 third-class passengers. The saloon will be 41 ft. by 40 ft. wide, giving accommodation for 140 passengers dining together. The officers and crew will number 120. This vessel, which is the largest merchant ship afloat, with the exception of the Great Eastern, was built in the short space of nine months, and the firm have a sister ship on the stocks for the same company. When the ship left the ways she was named the Iberia.

Safety-Lamps.—Mr. J. B. Stone, of Birmingham, has patented an invention which consists in improving the illuminating power of the said lamps by making the glass surrounding the flame of a cylindrical figure within and a convex figure without, or convex both within and without. By this means the light is so concentrated that when the lamp is hung vertically the illumination is for the most part directed horizontally at or about the level of the lamp. When the light is required to be directed upwards or downwards the glass is made of a conical figure.

THE STEAM ENGINE OF 1833 AND 1873.*

From the "English Mechanic and World of Science."

The period selected (forty years) is about identical with my own experience on the subject; and my object this evening will be to draw your attention to some of the main differences of practice in the two periods. In the neighborhood of Manchester, in the earlier period, the boiler pressure would be from 7 to 10 lbs. per sq. in. above the atmosphere; and the present pressure may be taken at about 70 lbs., which is about eight times greater now in excess above the atmosphere than at our first date. The engines mostly in use, and in course of construction, at the former period, for driving our cotton and woollen mills, were the stationary beam-engine, and the side lever or marine-engine; many being Watt's and Murray's make, and other copies of their productions.

The steam generator, or boiler, is so intimately connected with the steam-engine that I cannot draw your attention to the latter without making a slight reference to the former. I may just state, therefore, that the boilers mostly in use were the wagon or haystack, and the butterfly or fish mouth; also the cylindrical dish-ended, without flue; and the cylindrical flat-ended, with one flue, fired in the flue; the two latter kinds being mostly used for non-condensing engines. About 1840, or say seven years after our first date, considerable efforts were made to economize fuel, which resulted in the more general use of stronger steam, and a corresponding increase in its expansible force; perhaps thus following in the wake of the Cornish engineers, who had about this time successfully attained very high results in their application of these principles to the pumping-engines of that district. It was about this time that the double-flued, internally-fired boiler, began to be introduced in this neighborhood; and also various modifications of that form of boiler, all with a view to meet the demand for greater production, economy of working, and lessening the nuisance from dense smoke. On the passing of the Factories or Ten Hours Act, these demands were much stimulated, as it practically necessitated the production of twelve hours' work in ten hours, by the same engines and the old number of boilers. The impetus thus given to the economical driving of our mills and works has continued up to the present time, and is at this moment of perhaps greater importance than at any former period, owing to the very largely increased cost of fuel compared with its former value.

The improvement made in the steam-engine itself during the periods we have named, does not consist in the invention of any entirely new model or class of engine, but rather of an elaboration and rectification of designs previously suggested or used; and in the selection of the simplest forms applicable to the various purposes and situations for which it is required. Notably, the horizontal form is one which is very generally applicable. It is not liable to the defects which were prognosticated, and which appeared inherent on its first introduction, namely, the rapid destruction of the cylinder and piston by the friction of their bottom surfaces by gravity; such tendency being almost wholly counteracted by other forces, as has been abundantly proved by very large experience. The vertical direct-action engine, overhead or inverted, has not proved itself so generally applicable as the horizontal, especially in the larger structures, partly from the difficulty in getting sufficient stability, partly the want of balance, and partly the inconvenience of getting to the various parts. The direct-action forms have, however, largely supplanted the stationary beam and side lever kinds, and would have done so more rapidly and effectually if the designers had not usually mutilated the proved effective proportions generally used in the older kinds, by cramping the new designs into very much too small a space to obtain their maximum effects. Indeed, the proportions used by the celebrated Watt, and other old engineers, have been proved so thoroughly beneficial and mechanically correct, that a strong prejudice exists in favor of long-stroke engines; and I beg to suggest that that is mainly because the old makers used such good proportions in the conversion of rectilinear into circular or rotary motion,—that is, the length of the connecting-rod relative to that of the crank or other medium of communication. The result of my own

* Read before the Manchester Association of Employers, Foremen, and Draughtsmen, by Mr. G. Saxon.

observation and experience is, that very much too little attention has been paid to these proportions; and I am not, therefore, surprised when our modern engineering, in such cases, compares unfavorably with the past.

Various examples might be adduced in confirmation of this experience, but I will simply name one, which is that of a firm of the most celebrated stationary engine makers in this locality—perhaps in the world—being engaged to supply a pair of vertical direct-action engines to compound with a pair of beam-engines of their own make, so as to economize fuel.

As I happened to be consulted about the same work previous to the contract being placed, and also engaged on other work for the same firm at the time, my attention was drawn to the extreme shortness of the connecting-rods in this case. I explained my views to the proprietor, who was so far convinced that he immediately communicated with the contractors, with a view of having the requisite alterations made, and the averred defects remedied. The response, however was that similar proportions were used in Her Majesty's Navy, and a desire to proceed with the original design, which was consented to. But mark the result! On the first day of starting these engines the slides on the bearing side ploughed fire, broke the crosshead and slide off one engine, and brought the machine to grief immediately. The disaster was remedied by trebling the strength of the slide, and doubling the rubbing surface of the slide block, and this arrangement continues to this day. It is not, therefore, surprising to find the result unsatisfactory.

As a contrast, amongst others I will quote the case of a small vertical direct-action overhead engine, which chanced to be on sale, with urgent delivery, to clear off, when I was just about commencing business at our present works. This engine had the very unusual property of more than the old standard proportion of connecting rod to crank (being eight to one). At the time I was perfectly satisfied with the price, and have since been with its performance; and if merit is to be the rule of promotion, I should place it in the van of the small fry. Like other engines, certain parts will necessarily decay, and require removal, but those parts which are usually affected by unnecessary friction are very long-lived in this one; and rude and small as the model may be, a most useful lesson may be drawn from its performance. It is still doing good work, and will probably long continue to do so.

Whilst on this part of the subject, I may mention that over twenty years ago, whilst engaged as chief engineer at a large engine works, I induced the proprietor to lengthen the whole list of horizontal patterns, and obtained highly beneficial effects. At the present time I am building a pair of horizontal engines with a proportion of seven and a half to one, which are designed to run at a moderately high speed of piston—576 ft. per minute.

During the period before specified, the oscillating cylinder engine, and the truck engine, have both—but especially the former—been largely used in special situations; notably for marine purposes, where economy of space is the first consideration. Their application for mill purposes, however, has been very limited; and it appears to me they will be still more restricted in cases where space is only a matter of secondary importance.

The double-cylinder engine of Wolff, now commonly called the compound engine, was hardly known at our earliest date, but it has gradually forced itself into use, until at the present time it has become almost as common for large structures as the single-cylinder engine, in consequence of its better adaptability for high pressures. Some engineers of note have disputed this, and maintain that the single-cylinder engine can be used with quite as great economy, and with a simpler machine. The results obtained by the Cornish pumping engines no doubt go to support this view, but the practical application of strong steam to rotative engines seems to demand its first introduction on the reduced surface of a comparatively small piston, acting through a considerable portion of the stroke, and to be afterwards expanded in a larger cylinder, whose capacity is several times that of the first one. Such engines I have found to give great satisfaction, both in comparatively large and small structures; and to work with a very high degree of economy, whilst the wear and tear is by no means excessive.

The practicability of using these compound engines is no doubt due to the great improvements which have been made of late years in the manufacture of boilers. Firstly, in having a better material readily

obtainable; and secondly, in a number of slight improvements of detail in construction, which, taken altogether, enable us to construct a good, sound, reliable vessel, up to 100 lbs. per sq. in., on the Cornish-flued, internally-fired principle, and to still greater pressures on the French, and small pipe systems. One great improvement in the internally-fired boilers has been the introduction of pipes in the flues, which, whilst they strengthen the flue, also increase the heating surface, and very greatly promote the circulation of the water, which is of the highest importance.

About twenty years ago a number of cases came to my knowledge where the flues had no pipes in them, and the feed water was passed through the mud hole at the bottom without being heated higher than the temperature of the hot well. The result was most destructive. The expansion of the boiler was most irregular, and caused the plates in the bottom of the shells to rip off alarmingly frequent. The remedy is to heat the feed water, and introduce it near the upper surface of the water in the boiler when working, and to apply pipes in the flues to obtain circulation.

While speaking of boilers, I may just remark, that two or three years ago, having taken a contract to supply a pair of compound engines, and my customer having determined on giving the order for the boilers to a firm who make it their especial business, he introduced me to the senior partner, in order that I might explain to him what kind of boilers it was desirable he should have. I insisted they must be plain, practical, simple boilers; and to carry a working pressure of 100 lbs. to the sq. in. The greatness of the pressure caused him to shake his head, and ultimately he took a week to consider of it, at the end of which time we again met; he smiled, and produced his specification, which was accepted. Since that time the same firm has made a number of similar boilers, and I believe they are quite as safe as those which they formerly made to carry a much lower pressure.

About the time of our earliest period, the Spur Fly Wheel, with the teeth on the outer circumference, was being introduced, as a substitute for the second motion fly-wheel, which had previously been generally applied. Owing to the slowness in the working of the earlier engines, the requisite uniformity of turning was best and most satisfactorily obtained by placing the fly-wheel on the second motion shaft, which revolved much faster, and the desired effect was obtained by the least quantity of material. This arrangement had, however, the defect of causing a backlash in the gear connecting the crank shaft with the second one, which, in some cases, proved an annoyance. The application of the spur fly, which has the merit of great neatness, enabled the engineer to get up the speed of the shafting rapidly; and many cases have occurred where this has been done to excess, such as a large wheel working into a relatively small pinion, causing a great loss by friction.

The improvements in the mode of moulding toothed wheels, and their greater accuracy, has enabled them to be run at a quicker speed than formerly; and the greatest advantage possible has been taken of this improvement, to obtain the highest speed of piston practicable. Some engineers, however, myself included, do not use the spur fly, but a wheel of less diameter, either bolted to the arms or otherwise, which arrangement allows a much greater velocity of crank shaft and consequent speed of piston, whilst the wheel teeth are run at a safe practical speed, and at such a velocity as to obtain the necessary momentum with the least weight of material, which is very important, in order to keep the bearings cool and to reduce the friction.

In the earlier engines the pistons were packed, so as to prevent the passage of steam, by the insertion of a hempen gasket, which was compressed by a junk-ring or follower-plate, secured by the requisite bolts. It soon, however, became a desideratum to find a metallic substitute for the gasket. Various plans were proposed, and some were in operation at our early date; but about 1848 a great impetus was given by new inventions for this purpose, and the construction of machinery for reboring the cylinders of existing engines in their places, without removal. The importance of having a cylinder truly bored, and fitted with a good self-adjusting metallic packed piston, so constructed as to work with a minimum of friction, and yet not permit the escape of steam, can hardly be overestimated. Indeed, it is hardly possible to conceive the cost of material, labor, and serious loss by stoppages which were involved by using the gasket packed

piston; and these defects were largely increased as the pressure of steam was raised. My own experience and recollection of it, in one case, are simply appalling. Morning, noon, and night, the cover had to be raised, the follower tightened, or a new layer of gasket inserted; while it was quite an ordinary thing to come to a dead stand during the working hours, send for a batch of men, who would pull the covers off, examine every working part, and get to work again as soon as practicable. I must observe that, as the pressure of the steam in the boiler in the case alluded to was so extremely low, a tolerable vacuum was indispensable. A few years after my first introduction to the works, this engine, which was a side-lever one, made by Boulton and Watt, had its cylinder re-bored, a new metallic piston fitted, and supplied with stronger steam, when all difficulties immediately disappeared.

In most of the early engines the cylinders were steam-jacketed. Considerable difficulty was, however, experienced in keeping the joints steam-tight. From this cause mainly, they were gradually given up, and became almost extinct. They have, however, of late years been reintroduced, it is said, with advantage; but a great deal must always depend on the connections being kept quite distinct.

The working valves for regulating the admission and emission of the steam to and from the cylinders of steam-engines, and the various modes of operating them, have always held a high place in the estimation of the engineer. They are so multifarious in kind and character, that I cannot even attempt a general description of them at the present time, but shall just remark that the D valve of Murdoch is still largely used, and when made of good bell-metal, and properly packed with gasket, they are good up to say 30 lbs. pressure. The valve now most commonly used is the slide, with the steam pressing on the back, operated by rods moved by an eccentric. Other very beautiful arrangements of working and expansion valves have recently been explained to you, and will doubtless be fresh in your recollection. Whilst speaking of valves, it may be proper to remind you that apparatus has recently been devised for replaning the valve facings of side pipes, and other facings, in their places, without removal, and operates very satisfactorily.

The very great desirability of uniform speed of the steam-engine, whether lightly or heavily laden, had already received due attention; and during the period we have chosen, many highly ingenious devices have been suggested, with a view of obtaining the desired end more perfectly. The pendulous long-armed governor of Watt, acting upon a wing, or revolving vane throttle valve, answered tolerably well whilst the pressure and speed remained low, but as these became augmented a more sensitive regulator became desirable. In numerous instances this has been attained by running the pendulous governor somewhat above its normal or natural speed, and counterweighting it, so as to get the required speed of engine with a greatly increased sensitiveness, whilst the wing valve has been superseded by the equilibrium valve, which, when properly constructed and applied, is equally easy to move under any circumstances, such not being the case with the older valves, which required considerable force to reopen them when closed. The application of the "equilibrium throttle valve," I consider, is a great improvement of the modern engine; and the invention and attachment of the high speed governors, in several of their various forms, has resulted in our obtaining a very high degree of regularity in the working of steam-engines; although it must be admitted that the constant tendency to entirely shut off, and instantly reopen the steam communication, must be a severe trial of the strength of the various parts, and is especially undesirable in the larger engines. In consequence of this excessive action, I have generally been satisfied with the pendulous governor, with long arms, modified as just described, and acting upon a good equilibrium valve. This arrangement I find to give very regular turning, and is not nearly so liable to shocks as the very high-speed ones are.

At our early date the single-acting air-pump was almost universal, and the cover or top was placed immediately over the delivery passage of the water. This arrangement proved a great barrier to increasing the speed of engines, and it has been removed by elevating the cover a distance above the passage, so as to form an air receiver and cushion to ease the delivery of water. The double-acting air-pump has been frequently and beneficially employed, especially for high speeds. As a rule, the vacuum obtained is not so perfect as in the older arrangement, but its other advantages,

in certain cases, more than counterbalance the defects.

Condensers formerly were exclusively of the injection class, and for land engines generally remain much as they were, except that owing to the increased speed they also have had to be made larger. The surface condenser is of great value to the engineer. In many cases where it is undesirable that water used for condensation should be also used for the generation of steam—and which is generally the case with marine engines—very considerable ingenuity has been exercised; and in several instances satisfactorily, to get a good surface condenser.

The locomotive, portable, and road engines have received the careful attention of the engineer during the period embraced by our review, and this has resulted in an astounding development in their application. Like the stationary engine, however, the improvements have necessarily been of a detail character, as the main characteristics were settled at the opening of the old Liverpool line. Very great minor improvements have, however, been effected; as an instance of which I may name the link motion, which very beautiful arrangement permits a very rapid and safe reversal of the motion, and also at the same time gives us a means of varying the expansion of steam to suit the various requirements. The link motion is now generally employed where steam engines are required to revolve in alternate directions. The radius parallel motion of Watt for guiding the piston rod in its many varied forms is not so generally employed as formerly; but has been largely superseded by fixed guides or slides, which, being simpler, have been preferred in the various kinds of direct-action engines.

The improvements which have been made in the various tools and machines used by the engineer have enabled him to execute a much more durable and solid structure than formerly; and to dispense with some of the rude and costly modes of connection formerly used, as, for instance, rust joints, which are now almost obsolete. India-rubber has been of especial service both in the form of washers and valves.

Steam hammers, which have been almost wholly invented and brought into very general use since our early date, demand at least a passing notice, if only on account of their enormous importance at the present time. They have almost revolutionized some branches of business to which they have been applied, but they are sufficiently important to demand a special notice or paper, and so we will leave them.

THE POLLUTION OF WATER.

From "Engineering."

In "Notes on Sewage," which will be found in a series of articles in the two preceding volumes of "Engineering," numerous, chemical difficulties have been mentioned in regard to what is called "sewage contamination." The determination of this in various specimens of sewage, in ordinary water supply, in wells, etc., is yet far from satisfactory. The most eminent chemical authorities differ not only in respect to the results they obtain, but also in the methods they employ for its determination. The matter is of the highest importance in regard to sanitary conditions, for on the weight of evidence given on either side at a trial at law or equity the pecuniary results may prove serious, and in some cases ruinous to the parties concerned. We are glad to be able to give some interesting results lately communicated to the Academy of Sciences at Paris, which promise, to some extent, a solution of the difficulties which the problem presents.

There are chiefly two tests by which the sanitary character of water, either of the ordinary supply, of wells, or of the effluent of a sewage farm, or the chemical treatment of sewage, may be estimated, viz., that of the physiological effects, and that by chemical analysis. The physiological method is that which is evidenced by the production of a certain class of diseases of the typhoid form from the use of impure water, of which instances are too familiar to require description. They exist in almost every large town; and, in fact, show the necessity of instant action for their prevention. But the physiological test is only of use as an indication of evil. It is, therefore, essentially followed by the che-

mical examination, which, as we have just stated, is at once difficult and uncertain.

Careful observation, however, has shown that all the diseases of the kind to which we have referred, are invariably associated with the presence of decomposing bodies containing nitrogen, either in the water supply or sewage. The source of this nitrogen is, for all practical purposes, as invariably derived from the refuse of animal existence. This nitrogeneous refuse is composed of nitrogen, hydrogen, carbon, and oxygen. The ultimate products of the decomposition of such refuse are ammonia, carbonic acid, nitrates, and nitrites. Now these latter are all harmless *per se*. It is at the intermediate stage—that is, the conversion of the refuse into these products—that danger arises to the animal system. But the presence of sulphur adds another element of danger, for by its respective combinations with hydrogen [sulphuretted hydrogen] and with nitrogen and hydrogen [sulphide of ammonium], the two most dangerous gases which we have here named in brackets, as products, are afforded. But for our present purpose we entirely omit the consideration of the sulphur compounds.

It is evident, therefore, that if the chemist detect ammonia, nitrates, and nitrites in any water, he may conclude that animal nitrogeneous matter has been the cause of their production. As a rule this conclusion is invariably arrived at, as will be seen in the weekly or other reports of water-examiners, medical officers of health of our large towns. But as will be presently seen, other causes of the presence of ammonia exist, utterly unconnected with the animal nitrogeneous refuse. It is this point to which we wish to draw special attention in the present article.

In England and France numerous instances have occurred in which gas works have been blamed for rendering water impure. In France actions have been brought and damages obtained against the companies who have been charged with injuring wells, etc., by the infiltration of water from their works. M. Boussingault has recently presented a paper to the Academy of Sciences, in which the experiment and results obtained by M. Musculus are fully detailed. Aware of the difficulty of the subject that chemist endeavored to find a test by which the injury to well or other water could be distinguished as caused by sewage or gas waste, and his plan may be briefly explained as follows:

In examining water thus rendered impure he supposes that the presence of ammonia has hitherto been the crucial test of the cause of the pollution. But sewage water invariably, if freshly produced, contains urea, while gas-refuse liquid contains none. If, therefore, urea be found in the liquid it would certainly point out to sewage as the source of contamination. But urea, on decomposing, produces ammonia, which is also contained in gas refuse, as above stated. He, therefore, sought for a means of detecting urea, and has succeeded in producing a kind of test-paper which seems well adapted for the purpose.

It appears from his researches that while urine is undergoing alkaline putrefaction small globules of a fermenting body are precipitated to the bottom of the vessel, and it is to these that the conversion of the urea into carbonate of ammonia is due. He pours the whole of the urine into a filter. At first the liquid filters rapidly, but gradually passes much slower. This he ascribes to the globules of ferment obstructing the pores of the filter, and remaining therein. The filter is then washed with distilled water to remove all trace of alkali, and carefully dried at a temperature of 35 deg. to 40 deg. C. It should be colored with a little tincture of turmeric, again dried, and then enclosed in a dry vessel to keep it from the action of moisture. The paper thus contains in its pores the globules of ferment, which are inactive so long as they are kept dry.

To use the paper as a test for urea, a piece is immersed in the suspected liquid. Small brown spots will appear if urea be present, because by the action of the ferment it is converted into ammonia, which thus shows the usual alkaline reaction on the turmeric, and as the quantity of the ammonia increases the paper will gradually become browned wherever a globule of ferment exists. It is necessary to remove all alkaline carbonates previously in the liquid by dilute sulphuric acid, or deceptive results, arising from their action, would be afforded. He has attempted to make this method a means of discovering the total amount of urea present in a liquid. For this purpose a piece of paper is placed in it, a little tincture of litmus, and as much dilute sulphuric acid as will give the liquid the tint of the peel of an onion. The whole

is to be heated for 5 or 6 hours to a temperature of 25 deg. to 30 deg. C. By the fermentation produced the urea will be converted into carbonate of ammonia, and hence by the usual method the amount of urea may be calculated. According to M. Musculus, the presence of uric acid, of albumenoid substances, and neutral salts, does not affect the accuracy of the results obtained.

Such is an outline of the plan proposed by that chemist. It is evident, on consideration, that it affords, so far as can be at present known, a very ready test for the cause of impurities in wells, brooks, etc., in respect to the refuse of gas works and sewage contamination. Its great value consists in distinguishing the source of the nitrogen in the form of ammonia. We learn from the researches of Lehmann and others that an adult fed on average animal and vegetable food will void about 500 grains of urea daily; one on purely vegetable food about 348 grains; and one on purely animal food about 821 grains, falling to but 240 grains in a person using food from which nitrogen was carefully excluded. The average of urea in urine is about 14.25 parts in 1,000 of the liquid.

Some very interesting points suggest themselves in this new method. Its value in distinguishing the difference between the effects of impurity arising from gas refuse and sewage, will be of great importance in jurisprudence. But as bearing on the results of various processes of treating sewage by irrigation, precipitation, or other means, it seems to open out a large field of inquiry that may be of essential service in controlling other methods of chemical analysis. The errors which we have seen in respect to the latter, as applied to effluent water of any of the existing sewage processes during the last three or four years, would hardly be credited by our readers, whether we refer to the ability of, or the mistakes which have been made by, various analysts. Perhaps M. Musculus may have put us in a new direction that may afford more satisfactory results than have been as yet attained.

ENGINEERING—ITS EFFECT UPON ART.*

From "The Builder."

Mr. Driver commenced his paper by giving a definition of art. Art, he said, was old, and dated from the first mention of man. He contended that it was universal and essentially human. The results of the work of many birds, insects, and animals were artistic, but in carrying out their work they were but following a line of action they were unable to alter. Art was therefore, human in that it was confined to man. All alterations of form and color done with an intelligent idea of arrangement was art, and therefore all manufacture was art. Wherever man was found, there also was art to be found, in some shape or other. Good works of art were rarely imitations. The design or art of manufacture was the choosing and placing of form and color so as to enhance all the other forms and colors to which it was opposed. Fine art was that in which the hand, head, and heart of man worked together; and the effect of that combination was seen in painting, sculpture, music, and poetry. As in art, so in engineering: it could be traced to the earliest period of the world's history; it could be taken to mean the art or science of construction; it was only another name for construction, and it was, therefore, universal. Nothing was too vast, nor was anything too small, to be undertaken by the engineer. A people might live without painting, sculpture, music, or poetry, although it would be a dreary world without them; but it would be utterly impossible to exist without the mighty science of engineering. It was the most necessary, and the root and foundation of all sciences. Neither the astronomer, the chemist, nor the artist could do without it. It was difficult to say how dependent the art of war was upon engineering. Art and engineering had been at all times coexistent, but while art was dependent upon engineering, the reverse was not the case. Many of the grandest artistic effects had been produced not so much by the architect as by the engineer; the roads, aqueducts, and other great works of the Romans fully

* A paper read before the members of the Civil and Mechanical Engineers' Society, by Mr. Driver.

proved what great engineers they were. In the grand old cathedrals there was to be seen the evidence of the engineering knowledge of our forefathers. Engineering had both a good and a bad effect upon art. As one of its good effects, might be mentioned printing. The thoughts and the words of poets, philosophers, and other great men, which at one time were confined to a very few persons, were now so nullified as to be brought within the reach of almost every one. By the multiplication of artistic works, both art, artists, and the art-loving public were greatly benefited. It was also true that there were evil effects upon art caused by engineering; but whatever they were they resulted from misapplication. When it ceased to be truthful, when it endeavored to make an inferior material represent and pass for a superior material, then it had an evil effect. Speaking of the relative position of engineering and art, he said he did not wish to place the former above the latter. Art was the superior of engineering, which should be the servant of art. Art should supply the master-mind, and engineering should be a useful workman. In conclusion, Mr. Driver spoke in favor of combining the work of architects and engineers together. He considered that each should know something of the other's work, and he believed that it would be very advantageous for a practising engineer to have an architect as a partner, and *vice versa*. He also believed that young engineers would be greatly benefited by giving some portion of their time to free-hand drawing.

A discussion followed the reading of the paper, in which Mr. Usill alluded to the difficulty of the engineer to produce an artistic work, owing to the very low price all contracts were taken at.

Mr. Whittaker was in favor of architects and engineers keeping to their own work.

Mr. Haughton referred to the difference between the art of construction and fine art, with the latter of which the engineer had nothing to do. By familiarizing himself, by the study of beautiful buildings and works of art, with an idea of what was a beautiful object, the engineer would be able to carry out his work in a more artistic manner. The buildings in London, he believed, would be erected in a superior style if the people of London were less deficient in their love of art.

THE CURRENT OF ARCHITECTURAL TASTE—THE STYLE OF THE FUTURE.

By G. HUSKISSON GUILLAUME.

From "The Building News."

In Mr. E. M. Barry's able lectures on Architecture, delivered at the Royal Academy, there is much for the student to reflect upon before he commits himself to a line of thought, or to any of those particular channels of art-fashion which are now so madly running their career. Leadership in art is now the ambition of the rising young architect, though, it is to be feared, an ambition attendant with risks and pitfalls, and, at any rate, with a very uncertain destination. Striking novelties must be the order of the day, no matter of what kind; whether borrowed, stolen outright from a remote age, burlesqued with a mixture of oddities, or as burlesquely rendered by the most serious and correct of Mediæval revivalists. Hence leaders must be found to supply the demand; a temptation is at once offered to those who have something new, or it may be something extremely old, to introduce No matter what the motive may be—conceit, wealth, popularity—so long as the idea is startling and vivid, there is a good chance for any enterprising young architect to supersede an already "well run" leader. The chances may be against him, but he can wait till an opportunity opens. To stem the current of an already popular fashion is not to be accomplished by an effort of mere denunciation or even reason, so much as by substituting a new one. Our fair friends, or those of them who lead the *beau monde*, know this; and can change the fashions whenever they can introduce a novelty, however far-fetched and extravagant it may be. In a fast age it is impossible to check this "ringing of changes," and, viewing the matter from the standpoint of human

nature, it is quite as impossible as it would be to lay down an iron rule in politics or Church government. We shall always have differences of habit, feeling, and taste; and as long as these exist, leadership in art and in politics must exist also. But changes are nevertheless determined by demands such as those created by civilization, utility, etc. It would be idle to deny this. The most rapid changes are those which spring from human needs; opposites are hit upon tentatively, not because they are required to meet the necessity, but because they, by a law of human instinct, give the immediate relief of our nature. So it was when the cold and bare theology of the last century was succeeded by the ritualism and objective form now in vogue; or when Classical correctness was superseded by an extravagant plunge into the opposite vortex of libertinism in art and literature. The change in both cases was beneficial only as avoiding the extreme and its attendant result. The popular mind, not seeing the exact condition it required, hastily took the leap, to be afterwards corrected. Thus the popular taste for art vibrates between opposites, though imperceptibly following the grander law of equilibration. From a pedantry for Classic reproduction to the liberty of individual caprice we have unquestionably gained a freedom and a flexibility which will enable us to make the next movement still more approximate to our actual condition. It is not at all likely we shall retrace our steps, or return to the Art of Greece or Rome. It is more possible that the Queen Anne style, with all its defects, may be the next tentative, or perhaps some other equally remote approach to Classicism or Gothicism.

Now the popular taste is, as I have said, more easily led than educated. It is so in everything—legislative reform, ministerial mutations, Church government, social improvements, are all the direct or indirect effects of sudden changes, not preconcerted or well considered, but the impulses of leadership in itself as blind as any of the narrow conceits of art and fashion. But where the shoe pinches the remedy is quickly applied. In matters of fine art the remedy is slower.

As leadership, then, is at the root of art changes, we should expect at least some forethought on the part of those who set a new fashion. Architects, of all men, know the wants of mankind; utility lies at the root of their art, and we have a right to expect from them tentatives that shall not be wanting in the essentials of building, or in the higher motives of design. It would be folly not to expect another change as imminent in art as soon as we have something to introduce. It is a question only of what kind the next style will be. As I have said, it will not be a return to Greek or Roman art; it cannot be a further movement in the Mediæval direction; it may be Romanesque perhaps, Anglo-Italian, or some modification of the Renaissance; but whatever it be, it will depend upon architects themselves whether it shall be one in the right direction—a long-lived or fleeting one. This will depend primarily upon the application of that one test—namely, the sanction of utility. If our architects are to mould the new change, it is to be hoped that a discernment of the twofold capacity of architecture will be uppermost—that the scientific aspect of the change will take precedence, not the merely artistic; the progressive "idea," not the archæological.

The new "style," or change, whichever we call it (we prefer the latter), may, for aught we know, be one strictly scientific, springing from the tentative solution of new materials and modes of construction; if so, we should cordially welcome the change. Feeling and sentiment have been so worked to extremes by the ultra-Mediævalists, it would not be surprising if science this time claims the next prerogative for popular acceptance. We shall at any rate be leaping from one extreme to the other, and this appears, as we have seen, to be a condition of a past age. If the surmise be right, how are the young architects (putting aside their elder brothers) prepared? Will not the engineer stand the best chance of solving the problem, now that architects' heads are so muddled and hampered by an *embarras de richesses* of all "styles" and "ages?"

Mr. Barry's remarks in his recent lectures ably seconded our own which we have made from time to time. Church restoration—the seductions of antiquity—have robbed our rising generation of architects of what should have been their inalienable property in art, and another and fast-rising young profession have appropriated it. We mean the use of iron, artificial stone, new modes of construction,

and the thousand appliances and inventions science has thrown in our way. Until the rising architects see this—unblinded by the traditions of their profession,—and endeavor to make these their own, what chance do they hope to get from the future? The public will not be always satisfied by Greek temples, Chinese pagodas, and monkish churches and houses; their next demand will be for something altogether new, applicable to the wants of the age, and upon our young architects will remain the responsibility of moulding the next change or current of ideas into a form that shall be worthy of this nineteenth century, and not an ill-devised fashion which must be as quickly supplanted.

THE POSSIBLE IN COAL MINING.

From "The Engineer."

Some statements made not long since by Mr. Robert Hunt, Keeper of the Mining Records at the School of Mines, Jermyn street, in a communication by him to the Statistical Society, have been rather inexactly reported in some of the daily papers, as quoted in our own "Notes and Memoranda" of a few impressions back. What Mr. Hunt actually did state in reference to the limit in depth at which coal could be worked was this: Referring to his own past observations, conducted in concert with Mr. R. Were Fox, in the mine shafts of Cornwall, he roughly summarized his results as to the rate of increment of temperature with depth, by stating that for the first 100 fathoms in depth below the plane of invariable temperature, the increment of temperature was about 1 deg. Fah. for each 50 ft. in depth; that for the next 100 fathoms it was at the rate of 1 deg. Fah. for 70 ft., and for the next, or third 100 fathoms, at the rate of 1 deg. Fah. for 85 ft. in depth. The increase of temperature with depth in the metallic mines of Cornwall thus appears to be a decreasing series, and the temperature to be reached at some much greater depth might prove much below that calculated on the common assumption that the rate of increment is constant, and amounts to 1 deg. Fah. for each 50 ft. of descent. In reference to the limit in depth of coal working, Mr. Hunt also stated that coal mining was at present actually carried on in certain pits in Belgium at a depth of about 4,000 ft. From these quite independent facts he drew the inferences—first, that if coal working can be carried on profitably in Belgium at a depth of 4,000 ft., it may reasonably be assumed that it could be carried on in Great Britain at the same depth, and not improbably at even a greater one; secondly, that if the rate of increment of temperature with depth be a decreasing series in the coal measures, as it appears to be in the Cornish mineral bearing rocks, the limit for coal working might yet prove a good deal lower than had been very commonly predicted. We think these deductions perfectly legitimate, bearing in mind, however, that there are many extraneous causes present amongst the mineral lodes and mine workings of Cornwall, as pointed out in the writings of Mr. Fox and Mr. Hunt themselves, tending to perturb the rate of increment of hypogeal temperature, which either do not exist at all, or to a much less extent in the coal measures and in the shafts and ways of coal pits. Some of these disturbing conditions, more especially chemical action induced or increased by the access of surface or sea waters to the lodes, and possible electric currents, giving rise to chemical changes in the same, are of a nature to warrant the supposition that they should be less active as the depth becomes much increased; but these conditions have less application to the coal measures.

Our present object is chiefly to draw attention to some results of very recent researches, which render our predictions within narrow limits as to the temperatures that may be met with at any given depths greater than have yet been actually reached much less certain than before, and which point to conditions that may prove favorable or the contrary to the anticipations of those who urge that we may yet win coal profitably at depths vastly exceeding those hitherto reached. Men can possibly work for a short spell, aided by free ventilation, in an air temperature approaching 100 deg. Fah., but labor under such conditions is killing; and for continuous work in coal mining the limit of endurance is probably reached—at

least for white men—at about 80 deg. Fah., at which temperature the air of the working might be maintained by known methods of ventilation, though the rock or other solid walls around are even at 100 deg., or possibly more, at some small depth from their surfaces. An eminent natural philosopher, indeed, on addressing a Scottish geological society, is reported to have said that at whatever depth or temperature down to the lowest at which coal might exist, there it could be worked; that the question was merely one of adequate local cooling by ventilation with air previously artificially cooled. This, however, seems to be a mere mathematician's view of the matter, for, practically, coal will cease to be workable, whether physically possible or not, as soon as the total cost of bringing it to bank at any given locality exceeds that at which it can be brought there from some distant locality where the total charges, plus the carriage, are smaller.

It is thus of much more practical importance to discover the temperature likely to be met with at the extreme depths at which in other respects coal can be won and worked in our British coal measures, than to speculate upon what extreme of high temperature may find the limit of human endurance in hewing and getting it. It is not devoid of interest, however, to inquire what may be the limit in depth at which coal can exist at all, admitting the common assumption that hypogeal temperature, for many miles in depth at least, continues to increase at the rate of 1 deg. Fah. for each 50 ft. of descent. The experimental facts—some of very old date being known to Gensanne, a French chemist and metallurgist, very early in the last century—upon which one of the most lucrative and important chemical manufactures of the present day, viz., that of Young's patent coal paraffine, depends—prove that at a temperature far below redness, or between 700 deg. and 800 deg. Fah., coal is rapidly decomposed, not as in the red-hot gas retort, mainly into inflammable gases and coke, but into various solid and liquid hydrocarbons, with little gas and little coke. The same sort of decomposition, indeed, goes on very slowly at far lower temperatures, as is evidenced constantly in some of our more "fiery" seams of soft and rich bituminous coal, and more or less in all coal stored in large heaps, especially if aided by the presence of moisture. At half the temperature employed in Young's process of distillation, namely, at temperatures between those at which tin and lead melt, decomposition into liquid and solid hydrocarbons still goes on, though less rapidly. On the preceding assumption, therefore, it follows that at a maximum depth of 40,000 ft. coal as such cannot exist, and it is not probable that—even aided by the superincumbent pressure and in quite dry seams—it can have a permanent existence at even half that depth. At such great depths as between four and eight miles or more, coal, at the temperatures assumed, would probably be replaced by hydrocarbons like native naphtha or petroleum. It is indeed highly probable that such a process of natural distillation, which has occupied ages in completion, has been the origin of the mineral oil wells of the United States, of the great deposits of ozokerite in the lignite formations of Germany, and of many fossil hydrocarbons known to science. The depth of the sedimentary strata is so great that it is not impossible that coal beds existing as the lowest members of the carboniferous formation may be buried to a depth of even five-and-twenty miles from some parts of the surface. There is good reason to suppose that the great Westphalian coal-field which dips to the north may, like our own Newcastle field, extend beneath the North Sea, and, if so, exist there at a depth of many miles. But in that case, at depths exceeding four or five miles, it is not coal, but petroleum, that probably fills the seams. And this may be true as to seams *now* existing at very much shallower depths, if at some former period they have been covered to much greater depths by formations since removed by denudation. We may therefore conclude with some assurance, that whatever may be the increased powers of working, that science and inventive progress may place in the hands of our posterity, the limit of coal working can never be required to reach more than three or four miles from the surface. All this proceeds upon the rate of increment of hypogeal heat long commonly admitted by geologists. The researches of Sir William Thompson and of some others as to hypogeal temperature have tended to throw considerable doubt upon the longer admissibility of the view, adopted on certainly very insufficient data, that such a rate of increment could be true for great depths. Observations made during the last 50 years have, on the other hand, proved that this rate of increment is

by no means true for all parts of the globe. Nor it is even the same for not far distant shafts, or mines, or artesian wells. Nor does it hold good in some observed instances for the same shaft at different parts of its depth. These discrepancies caused the late Mr. Hopkins, of Cambridge, who examined the subject closely, to conclude that there was some unknown cause which disturbed the rate of increment of heat, irrespective of and in addition to the causes pointed out by him—the chief of these being a difference of conductivity for subterranean heat prevailing in different strata or superposed formations.

In a remarkable paper read before the Royal Society in June, 1873, "On the Nature and Origin of Volcanic Heat," and since published in the "Philosophical Transactions" for that year, a solution has been given of that "unknown cause" which it is highly probable is the true one, and which attributes the variations of hypogeal increment to the variable amounts of work transformed into heat in the different strata constituting the outer crust of our globe, by their tangential compression, produced by the contraction of our planet in its secular cooling, the resistance to which compression varies in different strata, and so also the heat of its transformation.

Space prevents our attempting to develop further here this curious and important deduction. We can only refer such of our readers as are interested to the paper itself; but meanwhile, from the abstract and profound investigations to which we have referred, two practical inferences consolatory to the future seeker for coal at greater depths than have been yet attempted may be extracted—first, that it is improbable that the temperature in descending does increase as fast as commonly imagined; secondly, that localities exist in which the rate of increment is *slower* than in others, and *vice versa*; and that it is possible to predict situations—whether in coal measures or in other formations—within which the rate of increment shall be found the least within the whole area of choice.

STEEL AS A BUILDING MATERIAL.

From "The Building News."

It can hardly be questioned that the great International Exhibition of 1851 gave a great and permanent stimulus to every branch of British manufacture, and that for the last twenty years there has been a steady progress visible in nearly every kind of workmanship both as regards quality and cheapness of production; but in scarcely any branch of manufacture has the advance been so marked as in that of steel. Formerly the labor and cost of converting iron into steel was so great that its value in the market was out of all proportion to that of common iron, and its application was confined to the cutler's art, the making of tools, and occasionally to some portions of machinery which required to be of a hard and durable nature. At the present time we find that steel is used in the largest parts of engines, in the tires of wheels for locomotives, for boiler-plates, railway bars, girders, and cannons; and that the price of cast steel is not more than double that of wrought iron.

Much of this great change, and of the extension of steel to large works, is owing to the improvements which have been introduced by Bessemer, Siemens, and others, into the process of converting common pig-iron into good cast steel. The material technically called "steel" is compounded of two ingredients, namely, pure iron and carbon, the proportion of the latter varying from $\frac{3}{8}$ to $1\frac{1}{2}$ per cent., according to the quality of steel required and the uses to which it is intended to be put, the smaller quantity of carbon producing a tough and ductile metal, and the larger quantity one that has great tensile strength, but is at the same time hard and brittle. The process employed for producing the finer kinds of steel from crude iron which is still in use, and was until the last 20 years the only one known, is a long and expensive one, occupying 15 to 20 days, and a large amount of labor in the manipulation.

The pig-iron is melted, refined and puddled, in order to remove the surplus carbon as well as all other impurities by oxidization; it is then hammered or rolled into bars of malleable iron, and again purified by manipulation in a charcoal furnace. Pure iron being thus obtained, the bars are packed with powdered carbon in large

chests of fire-brick, and kept at a white heat for several days. The material has now been transformed into "blister steel," the bars are broken up into small pieces and sorted according to their quality, then melted in crucibles holding 40 lbs. each by placing them in a powerful air furnace; after exposure to heat for three hours the crucibles are removed from the furnace and the metal poured into moulds, forming ingots of cast steel ready for working up into any required form. In this operation the consumption of fuel is about 4 tons of coke to every ton of metal that is melted; and when large ingots are required several crucibles have to be used, and a continuous stream kept up from them in succession, so that the risk and expense are greatly increased.

Steel in large masses is now required by the engineer and machinist for structures or engines subjected to heavier strains than ordinary iron will bear without yielding. For such purposes steel must be of sufficient toughness to allow of being twisted or bent cold into almost any form without injuring the fibre, whether the force is applied gradually or by sudden impact. Its tensile strength must be at least half as much again as that of the best wrought iron, and it must be soft enough to be turned readily in a lathe, bored, or cut by file and chisel. The kind of cast steel which is wanted for engineering purposes is one that will take any form in the moulding machine or under the steam hammer; yield readily and quickly to the action of cutting and shaping machines, and yet retain all the toughness of the best malleable iron with a great increase in tensile strength. The process adopted by Mr. Bessemer is one that enables the manufacturer to judge to a nicety what kind of steel he is producing, and to regulate the operations so as to obtain exactly the quality he requires. The crude pig-iron is converted into cast steel by one process which occupies not more than 30 minutes of time. It is first melted in a reverberating furnace and then run into the converting vessel, the interior of which has first been heated by coke under an air blast driven in through perforations or tubes called "tuyeres" in the bottom of the vessel. The converter being supported at the centre on pivots, can be reversed at pleasure, and when it has been heated sufficiently it is turned over to allow the unburnt coke to fall out; being then turned on its side the melted iron is poured in, and the blast turned on; the vessel is then righted and the air rushes up through the numerous tuyeres into the molten mass and sets it in violent agitation. The silicon which the iron contains first combines with the air and with some oxide of iron, and forms a fluid silicate of oxide of iron, the whole of the silicon being oxidized in a few minutes by gradually increasing the heat. When the silicon has been got rid of, the carbon of the iron unites freely with the oxygen, producing intense combustion with violent ebullition, and exposing a very large surface of metal to the air; and the flame rushing from the top indicates to the experienced workman the condition of the molten mass within. Just as the metal is approaching the condition of malleable iron, the blowing is stopped and a small but carefully measured amount of charcoal-made pig-iron, having a known proportion of carbon in its substance, is introduced into the converter, and in a few minutes the whole mass becomes steel of the desired degree of carburation. It is then poured into casting-ladles which have plugs of fire-clay fitted into the bottom so that the metal can be drawn therefrom into the moulds without being mixed with any floating impurities. The whole process, from the time of pouring the melted pig-iron into the converter to the time of casting the ingots of steel, occupies only 30 minutes, and instead of pounds of metal only being produced, as in the old process, we get tons; no fuel is required in the manufacture beyond that used in melting the crude iron and heating the converter, and there is no manipulation whatever in the whole operation. When small quantities of steel are made, the loss of weight upon the crude pig-iron used in its manufacture is somewhat about 14 per cent., but when made in large masses the loss can be reduced to 10 per cent.

It is possible, by means of the steam-hammer and the rolling-mill, to give steel a tensile strength three times as great as that of wrought iron; but the material thus operated upon is too hard and unyielding for the purposes of the engineer, the most useful metal being that whose tensile strength is from 40 to 50 tons per sq. in., and the proportion of carbon from five-eighths to three-quarters per cent. This ratio gives a steel possessing a maximum degree of toughness, yielding to any extent

without snapping, but requiring a far greater force to bend it than wrought-iron does; it is also capable of bearing heavy blows without being fractured, and is less liable to crystallize by vibration than any other metal. When the proportion of carbon exceeds three-fourths per cent., the metal has a greater tensile and compressive strength, but it loses its toughness and becomes too hard and brittle to be worked with the hammer or chisel.

Siemens' method of converting iron into steel consists in melting wrought iron in a bath of liquid pig-iron, the whole being made into steel by means of very high temperature and the non-oxidizing flame of the regenerative gas furnace. The decarburized iron is thrown in measured quantities at regular intervals into the bath of pig-iron, the operation being completed by an addition of pig-iron which contains manganese in known proportion.

By either the Bessemer or the Siemens process large castings of steel can be obtained which, without having to undergo the process of hammering, rolling, or any other mechanical compression, possess a high degree of strength and tenacity, and having no liability to fracture under heavy blows even during the most severe cold of winter.

We will now briefly allude to the uses to which this valuable material has been turned by the engineer and architect, and consider what further application to constructive purposes it is capable of. Cast steel into which the proper proportion of carbon has been infused possesses all the excellent properties of wrought iron in a high degree, and is at the same time free from the defects of that metal; so that it can be employed for every mechanical and constructive purpose where great ductility, tenacity, incompressibility and transverse strength are required. Hitherto it has chiefly been used in the construction of various parts of machines, steam-boilers being made with steel plates 5-16 in. thick which will safely bear a constant pressure of 100 lbs. on the sq. in.; it is also used for the tubular boilers of locomotives, and for these purposes it is admirably adapted, since the rivet holes can be punched close together without fear of splitting the small strip of metal between them. Fireboxes of locomotives are made by rolling a sheet of steel from a cast ingot and then hammering it up so as to make it perfectly free from all joinings or weldings. Steel is entirely superseding iron for the tires and axles of locomotive wheels, also in the shafts, cranks, and piston-rods of marine and other large engines; for the cylinders of hydraulic presses, the blades of screw propellers, cogged wheels, and for nearly all parts of machinery which are subjected to heavy strain or constant friction. Steel rails for the permanent way of railroads are now being used in the place of ordinary rolled iron ones, especially where the traffic is very heavy, it being found that a good steel rail will last nearly twenty times as long as one of rolled iron, so that not only a great saving is effected in the expense of the material itself, but also in the labor required in laying and repairing the line. Plates of cast steel are extensively used instead of iron for shipbuilding, by which means the weight of the vessel can be diminished at the same time that its strength and durability are increased; and there is little doubt that on this account steel will eventually take the place of iron for the armoring of men of war, as it has already done in the construction of the heaviest ordnance with which those vessels are armed.

Steel wire rope is used for lifting heavy loads, as in hoisting cranes and for other purposes where great tensile strength is required; it has also been employed in the Albert Bridge at Chelsea for the catenary or curved cable from which the slanting chains are suspended by vertical rods in order to preserve their equilibrium; this cable is 6 in. in diameter, and consists of a series of strands of straight steel wires bound together by a smaller one coiled over them. Steel has for some years been employed as the material of coiling shutters, which are lighter and more durable when made of this material than of any other.

In the main parts of building constructions steel is gradually being introduced, solid pillars of this material having a great advantage over those of cast iron, taking up less room, and being able to bear with safety a weight much nearer the breaking load than those of iron will do: so that even if they are bent under the load they will return to their original straightness as soon as the load is lightened, and the elasticity not be injured by the extra strain. Another great advantage possessed by columns of steel is their non-liability to

fracture from sudden blows; they are also capable of standing any amount of heat in case the building in which they stand should take fire; nor will they be liable to fracture if cold water is thrown upon them when in a heated state. The strength of steel columns may be considered as double that of solid cast iron ones of equal size, when the length is equal to about 30 diameters, and still more than that when the length is greater in proportion to the diameter.

Since steel can be rolled or hammered into railway bars, joists of similar section can be advantageously employed for fireproof floors, and having double the strength of wrought iron, they will not be more costly even if the price per ton is double, while they will press with only half the weight upon the wall. These may be made to rest upon I or box girders, formed of steel plates riveted together, the lower flange of such girders being twice the area of section of the upper flange; since the resistance to tension is only half the resistance to compression. Such a floor, containing only half the weight of metal that would be required if common iron was used, will bear safely a greater load, since the elastic limit is much nearer the breaking weight in steel than in iron, and its elasticity is unimpaired by a load that will cause considerable flexure. Girders and joists made of steel would not be twisted and destroyed by fire, as those of cast or wrought iron are; so that for large warehouses no better material can be employed. Roofs having their frame-work of steel would be exceedingly light and durable; the parts in tension, such as horizontal and vertical tie-bars, might, in fact, be of steel wire rope, and those in compression, of round or square bars.

Much more might be said as to the advantages to be derived from an extended use of cast steel in the construction of buildings, and it is to be hoped that architects will not be behind the engineers in applying so useful a material, especially as the numerous experiments which have been made by Fairbairn, Kirkaldy, and many others, enable us to judge of the merits of the various qualities and kinds of steel that can be produced.

GUN CARRIAGES AND MECHANICAL APPLIANCES FOR WORKING HEAVY ORDNANCE.*

From "The Engineer."

Owing to the increase in the size and power of ordnance since the introduction of armor, gun-carriages had gradually become elaborate machines, and the appliances for working the monster ordnance now in contemplation would tax all the resources of mechanical science. The first difficulty experienced in mounting the Armstrong rifled guns arose from the much greater violence of their recoil as compared with that of the old cast-iron guns; a disadvantage mainly resulting from their superiority in lightness, strength for strength. A self-acting brake for arresting recoil, designed and successfully tried at Elswick, in 1864, by the Ordnance Select Committee, on a 70-pounder timber carriage, was described. The great superiority of wrought iron to timber as a material for gun-carriages was next referred to, and experiments made in 1865 were cited, as showing the error of the popular objection entertained against wrought iron, on the score of its producing, when struck by shot, more numerous and destructive splinters than timber.

Some of the leading types of gun-carriages made at the Elswick Works both for naval and for land service were then described, commencing with the plate compresser or recoil brake, which was stated to have been adopted almost universally, and by nearly every Power in the world.

The series included the 12-ton gun broadside carriage, also the 18-ton gun naval carriage and slide of similar construction, but capable of revolving about a rear pivot as well as a front one, so that the gun might be shifted from one port to another adjoining, and be used in both. The special feature of the plan was the pivoting of a portion of the rack, by which means it could be made available for training the gun in both ports. This rendered unnecessary the turn-table now used for the same purpose, which was held to be objectionable in a ship; for a

* From a paper read before the Institution of Civil Engineers by G. W. Rendel, C. E.

large hole had to be made in the deck, the deck beams must be cut and space occupied below, besides which a serious and costly complication in the structure of the vessel was introduced.

In the 15-ton gun wrought iron carriage and slide for land service, attention was directed to the method of training the platform, and to the substitution for the usual tripping rollers under the carriage of a number of grooved rollers, permanently running on the slide. The training was effected by gear connecting the platform trucks on the front and rear rails in such a way as to drive them at a speed proportioned to the respective radii of the rails. The result was that the platform moved truly about the centre of both rail circles, required no actual pivot, and was trained with ease and rapidity by the simple traction of the wheels. By placing the carriage permanently on wheels, and trusting more to the compresser to arrest recoil, the operation of "tripping" the carriage, *i. e.*, of throwing the wheels into action for running out, was avoided, thus saving time, labor and exposure of men.

By the adoption of these mechanical arrangements, for the application of manual power to the working ordnance, guns up to 25 tons weight could now be worked with more ease, safety and rapidity, than guns of a fifth of that weight were formerly. The size of ordnance continued, however, to increase by rapid strides. There were already many rifled guns in existence of 36 tons or 38 tons weight, throwing 700 lbs. shot. Guns of nearly double that weight were actually being made, and there was no manufacturing obstacle to the construction of still larger guns. It was difficult, indeed, to place a limit to the size of guns that could be produced on a system like that of Sir William Armstrong, under which the gun was built up of concentric cylinders superposed in layers, whose number might be increased so as to form an immense total thickness, without involving any one piece of unmanageable dimensions. The powder pressure attained with large charges would, possibly, first impose a limit on the size of guns; but recent experiments and investigations gave ground for the belief that, even with charges vastly exceeding any yet used, the powder pressure might be regulated and kept within prescribed bounds. Hence, then, the adoption of some inanimate power in the place of mere hand labor, for loading and working heavy ordnance, desirable as it was for existing guns, became an absolute necessity for guns of the immediate future. The simplicity and compactness of hydraulic machinery, and the perfect control it gave over heavy weights, especially adapted it for the purpose. Hydraulic power sufficient for the heaviest gun might be transmitted through a very small pipe, for long distances and by intricate ways; so that a steam pumping engine might be placed in a fort or ship in such position as to be absolutely secure, and supply power, by this means, for working many guns. A detailed description was then given of some of the arrangements experimented with, or now in progress, for loading and working guns by hydraulic machinery. These arrangements embraced a new system of mounting turret guns, in which the carriage was dispensed with, and the gun was supported on three points, viz., on a pair of trunnions placed well forward and on a saddle under the breech itself. The trunnion arms rested in two sliding blocks, which ran in guides on fixed beams built on the floor of the turret. Immediatley behind each block in the direct line of recoil were two hydraulic cylinders for checking recoil and running the gun in or out. The saddle which supported the breech slide along a beam or table beneath it. The front of the beam could be raised or lowered by a hydraulic press to give any desired elevation, but the rear was pivoted at a point corresponding to the horizontal position of the gun; consequently the gun returned always to the horizontal position as it recoiled, whatever elevation it might be fired with, and cleared the port in coming back. Thus the advantage of muzzle pivoting, viz., the reduction of the size of the port-hole, was to a large extent realized without the necessity of lifting and lowering the gun itself.

In the system of mechanical loading for guns mounted in turrets, the gun was revolved and brought to a fixed loading position, when it was sponged and the charge rammed home by hydraulic power. The shot was brought up to the loading place on a small railway truck, controlled by a friction-plate, which clamped it to the rails whenever the truck-handle was lowered. It was then run on to a hoist, which rose between guides against stops, and brought the shot opposite the gun muzzle ready for being rammed home by the hydraulic rammer, consisting of a parallel tube in which

ran a piston and tubular piston-rod. The head of the rammer formed a sponge for cleansing the bore, and contained a self-acting valve which opened when pushed against the end of the bore and discharged a strong jet of water within the gun. A jointed rammer, used for positions where there was not sufficient space for the tubular rammer, was also described. The advantages attained by this arrangement were as follows:—The loading operation was transferred from a confined space and exposed position in the port of the turret to a roomy and convenient place on the main deck, where the apparatus was completely protected; the dimensions of the turret were greatly reduced; one man in the turret and one outside might direct and control all the movements of a pair of the heaviest guns, and might load and fire them without other help than that involved in bringing up the ammunition; and, finally, far greater rapidity of fire was attainable than would be possible by manual power. With reference to the necessity the system involved of turning the turret round always to one of two or three fixed loading positions, it was stated that the turrets of the Devastation made a full turn in 45 seconds, and that a railway swing bridge over the Ouse, constructed under the direction of Mr. Harrison, Pres. Inst. C. E., and weighing 800 tons, was turned with almost equal facility by means of hydraulic machinery. It was also stated, as a matter of fact, that the whole operation of bringing to loading position, sponging, loading, and placing again in firing position a 9in. 250-pounder turret gun, mounted experimentally on this plan, had been effected in 23 sec. The jointed rammer had been successfully applied on a garrison platform. In this case, as the rammer was fixed on the platform, there was no necessity for turning the gun to a definite loading position, and the loading gear and men working it were protected by the parapet. By the present method of loading barbette guns by hand, the men had to mount upon the platform in full view of an enemy, and besides being exposed to shell fire, they became the targets for a rifle fire, which, owing to the precision and range now attained with rifles, would render it difficult to keep guns in effective action under such circumstances.

In suggesting another plan for the application of a hydraulic system of loading in casemates, it was stated that there was no doubt more difficulty in the adoption of mechanical loading in existing casemate forts than in turrets or open earthworks. The size of artillery had so outgrown that of the existing forts during the long time necessarily expended in their construction that 38-ton guns had now to be mounted, if possible, in batteries originally intended for 12½-ton guns. But this fact made it only more imperative to dispense with manual power, because the larger guns, while they further restricted the already limited space, required larger crews. The service by large numbers of men of heavy guns closely ranged in confined casemates, tier upon tier, might lead to serious confusion in the heat of action; and the necessity of crowding men in time of war in isolated forts was of itself a grave evil. By substituting hydraulic for manual power for working the guns, nine-tenths of the men might be dispensed with, and the work might be done more coolly, rapidly, and efficiently. Rapidity of fire was nowhere of greater importance than in the case of guns designed to prevent the passage of swift steamers past fixed batteries; and economy of men was a vital consideration in the defence of a coast so extended as that of the United Kingdom. It was said that already far more guns were mounted than could be manned. Modern artillery could only be worked with highly trained men, whom it would be impossible to produce upon short notice. Nor could the present small force be made effective by activity in shifting men to threatened points, for the attacks of steam fleets would be sudden and unexpected, and could only be met by preparations at all points.

The introduction of an effective system of mechanical loading had an important bearing on the question of the comparative merits of breech and muzzle loading, because it enabled a gun, however long in the bore, to be loaded at the muzzle with at least as great facility as at the breech, while dispensing with the complications of breech mechanism and the time required to work it, both of which became important considerations in the case of monster ordnance.

The principle of sinking guns entirely under cover from horizontal fire behind any sufficient parapet, and raising them only to deliver their fire, possessed the great advantage of making earthwork defences available. All defences must yield to continued attack; and an iron fort when

seriously injured could scarcely be made good before the end of a war, and only then at great cost. It was the especial merit of earthwork, that it might be easily strengthened and adapted to new circumstances, and that it might be repaired almost as fast as it was destroyed. In the two forms of gun-carriage adapted for this system of protection, which had been proposed by Major Moncrieff, the principle was the storing and utilizing of recoil, in the one case by the raising of a weight, in the other by the compression of the air. The economical value of the utilization of recoil was insignificant where steam-power was available.

The main object to be obtained by the utilization of recoil was to make of each gun-carriage a machine complete in itself, and independent of any connection with other machinery for producing the required power. In a system, however, of hydraulic gun-carriages, supplied with power from steam pumps, the connection between the carriage and the source of power was the simplest kind, consisting only of a small pipe which might be furnished with a stop valve, and thus enable the power to be turned on or off with nearly as much facility as a jet of gas. As there was no limit to the amount of power that might be conveyed, so there was no restriction of the height of cover obtainable—an important point in the employment of earthwork as a protection for guns, since the crest of the parapet might easely be cut down by the enemy's fire. A drawing was exhibited of a 12½-ton gun mounted under cover of earthwork, so as to be raised to the firing position by hydraulic power, and the advantage of using a power independent of recoil for raising the gun was illustrated by the height of cover obtained. A working model was also exhibited of a 38-ton gun similarly mounted, as designed for the upper deck barbette battery of H. M. S. Téméraire — a vessel which, being intended for ocean cruising and provided in consequence with masts and sails, required a high deck and could not carry a revolving turret.

ON THE CONSTRUCTION OF A NEW MEAN NOON SUN DIAL.

By S. V. CLEVENGER.

Written for Van Nostrand's Magazine.

A self-equating dial may be constructed in the following manner:

Consider the gnomon as an upright pencil, perpendicular to a plane surface.

Determine the meridian line upon the surface passing through the pencil where it intersects the plane at right angles. (Chauvenet's "Spherical Astronomy," pp.429, 430, vol. i.

With the centre of the pencil as the centre of an arc of equations of time, describe 15′ angles radiating both sides the meridian line, making 16 of them on each side.

Find where the shadow of the pencil point will fall at mean noon, along the proper equation line upon a given day and in the given latitude, by taking the calculated apparent altitude of the sun at local mean noon, the rays being taken as secant to the gnomon, the shadows forming tangents to the pencil with its point as centre, and thus easily calculated.

Where these mean-noon shadow-points fall upon the plane surface, marks may be made and a continuous line drawn joining the points. In these latitudes this line forms a figure 8 with the ellipse nearest the stylus much smaller than the other, which is broader and elongated.

It facilitates observations to have the seasons painted nearest those parts of the line over which the shadow point passes at mean noon.

The gnomon may be constructed in a variety of forms. I have one on a dial, the base of the stylus of which springs from the north end of the surface and is arched above the figure, overhanging the centre of the equation arc with an adjustable point 5 in. from that spot. The advantage being in having but little of the dial shadowed during the noon hour.

It is interesting to calculate the various forms the mean noon line assumes in north and south latitudes.

The figure may be calculated for a given latitude, and used anywhere by inclining it at an angle equal to the difference of latitudes.

I first constructed one of these dials in A. D. 1869, and found it gave satisfactory time for all ordinary purposes. Several newspapers noticed my invention of the instrument at that date, but this is the first effort made to properly give its construction to the scientific world.

A machine can readily be made which would plot the line quicker than it could be calculated.

THE CHANNEL TUNNEL.*

From "The Architect."

For many years mining has been carried on under the sea. In Cornwall, in Cumberland, and in Northumberland, lead, silver, and coal have been won from strata under the sea, and in some instances the working has been so near the bottom that the action of the waves could be distinctly heard in the galleries. In Cornwall, at the Bottallach and Levant mines, galleries are driven considerable distances from the coast, and with the side galleries form a network some score of miles in length, and in some parts with a very thin stratum of rock between them and the sea. In Cumberland the galleries of one pit are between five and six thousand yards in length, and extend in a direct line more than 4,000 yards under the sea, yet the manager states that only an inappreciable quantity of sea water finds its way into the mine. Then, again, it is fifty years since Sir Isambard Brunel projected the Thames Tunnel, which, constructed for carriage and foot traffic, has recently been converted into a railway tunnel, and trains are now running through it every few minutes daily, and within a very few feet of the bottom of the river, which is here 1,200 ft. in width. The soil above the tunnel is of the loosest character, mud, gravel and sand, and in some parts not 20 ft. thick. This tunnel, the first constructed under a tidal river, and having for a considerable portion of its length 50 ft. of water above it, is now as sound and water-tight as any, and more so than many tunnels constructed inland.

Among the various tunnels which have been made for railways, one or two may be mentioned where difficulties arising from an excessive influx of water have been successfully overcome. The Kilsby Tunnel, from which for many weeks 1,800 gallons of water were pumped per minute, by the employment of 1,250 men, and 13 steam engines, was successfully driven at a cost of £145 per yard. The Saltwood and the Bletchingly Tunnels were also driven, in the face of great difficulties, at a cost of £118 per yard, at which rates 22 miles would cost £5,650,000 and £4,568,000 respectively. The Hauenstein Tunnel, in Switzerland, a very difficult work, cost £80 per yard. Ordinary railway tunnels, through chalk and such like strata, cost from £30 to £50 per yard.

Since the completion of these tunnels the art of tunnelling has advanced considerably, and with the aid of machinery to facilitate the operations of the workmen, and of arrangements for the supply of fresh air, it appears that no difficulty exists in piercing the hardest rocks and in forcing a way through them of almost any length.

The most interesting instances recently completed are, the tunnel under Mont Cenis, 9 miles in length, at a cost £206 per yard; and the Hoosac Tunnel, in America, nearly 6 miles in length, at a cost of about £180 per yard, both for the most part through very hard rock; and there are now three in progress—one under the Severn, a deep tidal river, 5 miles in length under the direction of Sir John Hawkshaw; another under the Mersey, under Mr. Brunlees; and the third under the St. Gothard, 10 miles in length, where the rate of progress is much more rapid than was made under Mont Cenis, the most recent return being at a rate of 14.6 ft. per day on the two faces. This increased rate of excavation is due to improvements made in M. Sommeiller's machinery, the result of the experience gained during its use in the Mont Cenis Tunnel. But M. Favre's rate of progress under the St. Gothard will be much exceeded by the use of Major Beaumont's new apparatus, and this rate will again be very much surpassed when working in the grey chalk, which forms the bed of the sea between Dover and Calais, by the use of Mr. Brunton's machine. All these machines are driven by compressed air, which, after driving the machinery, is used for the ventilation of the tunnel.

It has, then, been established during the progress of these tunnels, that tunnels of the size required for railways can be driven through strata whether consisting of loose soil or the hardest rocks, and that the powerful machinery employed, driven by compressed air, provides an adequate suppy of air for ventilation during construction.

Having thus referred to what has already been done in tunnelling for railway purposes, let me now call your attention to

* Ab-tract of a paper read before the Society of Arts, by W. M. Hawes, F. G. S.

the Submarine Tunnel proposed to be constructed under the Straits of Dover, but which, while exceeding all others in length, will not, from the nature of the stratum through which it will be excavated, occupy more time or involve greater difficulties than have been overcome in driving the tunnel under the Mont Cenis. The character of the stratum through which the Channel Tunnel is to be driven must determine not only the cost and the time required for its execution, but its practicability, and has therefore demanded the most serious and careful consideration by Sir John Hawkshaw and Mr. Brunlees, as well as by their French colleagues.

It appears to be generally acknowledged that the only place where a submarine tunnel can be made with a due regard to safety and economy is through the grey chalk which stretches across the straits between Dover and Calais, and, this being admitted, it only remains to show the cost of, and the time required for, the construction of a tunnel of such dimensions and length as to be practically available for general traffic.

First, as to time. The application of the machine for tunnelling through chalk or any soft strata, invented by Mr. Brunton, will so reduce the time required for the excavation of the tunnel between Dover and Calais that the period for the completion of the twenty-two miles may be determined almost to a certainty. At Snodland, near Maidstone, where it has been tried, a heading of 7 ft. in diameter was driven at the rate of 1 yard per hour. This rate, supposing the work to be begun on both sides of the Channel, would require only two years to drive a driftway from 7 to 9 ft. in diameter across the Channel; but, allowing for the delays and casualties which always occur in works of such magnitude, we may safely say it would be easily completed in two years and a half.

The machine has been fairly tested, and the simplicity of its arrangement affords the best guarantee of its successful application to working through a soft, plastic material like the lower or grey chalk. The action of the machine is twofold. It chips away the material from the face of the chalk by an unceasing operation, and it collects the débris produced, deposits it on a band, and finally delivers it into the wagons which are to convey it away.

With such a machine the cost of the excavation of the driftway may be accurately estimated. The cost of the tunnelling machines, the air-pumps and pumping engines for drainage and for raising the chalk as excavated, can be easily determined. The hand labor to be employed is also capable of accurate estimate, and would be limited in amount, as the tunnelling machinery would be worked by compressed air, which, whilst driving the machine, would also ventilate the driftway; and the charge for interest on capital and for management during construction can be fixed and limited.

The most careful calculations estimate the cost of the driftway at £1,000,000. The driftway being completed, the cost and time required for its enlargement to the size of a railway tunnel could also be as easily estimated; and it may be assumed that should the driftway be driven successfully 1 or 2 miles under the sea, the enlargement might be begun without waiting for its completion across the Channel.

If this course be pursued, the entire work may be completed in five or six years, and at a cost of from six or eight millions of money; but until the driftway be carried a certain distance under the sea, it is almost impossible to give more than a general idea of the time which would be occupied in completing the work, or the expenditure it would involve.

The shafts on each shore will be sunk to the depth of 450 ft. below high water mark. From the bottom of the shaft driftways will be driven for the drainage of the works whilst in progress, and for its permanent drainage after completion.

The tunnel will commence 200 ft. above this driftway, and will be driven at an inclination of 1 ft. in 80 to the junction with the drainage driftway, and then at a gradient of 1 to 2,640 to the centre of the straits, where the tunnel from the English shore will meet that driven exactly in the same manner from the French shore, and, being united with it, will complete the submarine railway under the Channel. The drainage will be from the centre of the tunnel to either end.

At present I have only referred to ventilation during construction, respecting which, so long as the excavating power is obtained by the use of compressed air, there is no difficulty. The results obtained during the construction of the Mount Cenis and St. Gothard Tunnels are conclu-

sive on this point. But for the ventilation after completion, I will confine myself to the statement of our distinguished engineers, that there can be no difficulty in obtaining by mechanical means a steady current of air through the tunnel at all times, quite sufficient to maintain the purity of the atmosphere. The exact method by which this will be accomplished need not be stated at present; it is sufficient to know that there is a general agreement of opinion by the English and French engineers as to the facility with which perfect ventilation can be maintained.

It is proposed, then, to establish in France and England companies to raise £160,000, and to begin the works on both sides at once; and so soon as the driftway is bored a sufficient distance under the sea to prove the accuracy of the calculations of the English and French engineers, and the practicability of the work, to take measures to bring this great undertaking before the various governments and capitals interested in its success, with a view to the ultimate provision of capital for its completion.

Sir J. Hawkshaw expressed his opinion that the project was practicable, and would one day be accomplished. The capital of £10,000,000 seemed large, but that included some miles of railway, both on the English and French shores, and the cost per mile would not come near the cost of the Metropolitan and District railways. The practicablility of the project would be tested by an experiment that would not be very costly.

Mr. Bateman said he was anxious to see the project carried out; but it presented so many uncertainties and so many difficulties, that he could not recommend the attempt to be made. No human being could say that there was not some dislocation or fissure in the submarine line between Dover and Calais, and if such were the case, no human power could contend with the pressure of some 400 ft. of water from an ocean channel. He thought the project was hazardous, and would prove a failure.

Mr. Rawlinson did not think there was any reason to suspect the existence of a fissure in the bed of the channel. It seemed to him that Mr. Bateman blew hot and cold on the question.

Mr. Lawrence suggested that twenty-five borings should be made to test the bed of the channel. That could be done for £25,000. Mr. Jones, Mr. Baird, and others continued the discussion; after which a vote of thanks was passed to Mr. Hawes for his Paper.

THE APPROXIMATE VALUE OF A REDUCTION OF RULING OR MAXIMUM GRADES.*

By JOHN G. CLARKE, C. E.

At the request of some professional friends, the following method of obtaining approximately the value of the reduction of a ruling or maximum grade on a railroad, is respectfully submitted for the consideration of the Society. For the basis of the paper, the writer is indebted to the late Charles Ellet, Jr.

The want long felt by engineers on location, of some method by which they may feel assured that the expenditure which they make to reduce the ruling grade is legitimate and proper, has given birth to many empirical formulas, none of which, so far as known, are at all satisfactory. It is not claimed that the formula now presented is exact; because the very foundation—the amount of business that the road shall do—is conjectural; and in order to obtain a formula which can be applied readily, values which are not mathematically accurate are admitted; but these errors are of small importance, and it is thought that when a pretty close estimate of the value of the grade, upon the conjecture that it is to do a certain amount of business, is arrived at, it will be near enough for all practical purposes.

The value of the reduction being the effect which such reduction will have on the cost of transportation, this cost is divided under three heads:

First.—The cost of repairs, etc., to road (not including cost of relaying track). This is evidently *constant per mile.*

Second.—Deterioration, caused by transportation of materials; as repairs to track due to weight of freight; expense of re-

* Transactions of Am. So. of Civil Engineers.

pairing and renewing cars; also expense of agents, force of all kinds, and contingencies, with interest on cost of cars; the items under this head are *constant per ton per mile.*

Third.—Locomotive power. This embraces expense of repairs to track due to weight of engine and tender; cost of repairing and renewing engine and tender; interest on first cost; cost of fuel, etc., and wages of engineman, fireman, and conductor. This item of cost is *very nearly constant per mile run by the engine*, and, for this discussion, is assumed at 40 cents; the proper number for one class of engines would, of course, be slightly changed for another, but the variation from the average is not large.

In speaking of quantities as constant, it is evidently meant that they will be constant for any particular road, regardless of grade; they will, of course, vary with each road, depending upon locality, management, traffic, etc. The cost of the items under the first two heads being independent of the grade, its value is therefore to be measured by the reduction of the cost of motive power which it entails, or what is the same, the reduction of the total number of miles which the engines are obliged to travel in consequence of being able to carry the larger load; and thus, it is not the height of the summits, but the *rate* of ascent that is to be considered.

Let W represent the gross weight in tons in full trains, carried annually one mile in the direction opposed to the maximum grade, and A represent the average gross load in tons an engine can draw up this grade; then $\frac{2\,W}{A}$ will equal the number of miles the engines travel annually, and $\frac{2\,W}{A} \times 0.40 = \frac{4\,W}{5\,A}$, will be the annual cost of motive power in dollars.

The rolling friction of car wheels being taken at $\frac{1}{3\,3\,0}$ of the weight, or about 6 lbs. per ton, the force of gravity and friction on a grade of 16 ft. per mile is twice the resistance of friction on a level; on a 32-ft. grade, three times; on a 48-ft. grade, four times, etc. Then if T equal the gross load an engine can draw on a level, and X equal the maximum grade—

$$T \times \frac{16}{16 + X} = A,$$

and as on low grades the weight of the engine is small in proportion to the weight of the train which it draws—in order to obtain a formula which can be used—its weight may be assumed to vary with the weight of the train, and thus the formula found above may be applied to the train alone, without considering the weight of the engine.

In the very able report of Mr. Silas Seymour, on the change of grade on the Union Pacific R. R., west of Omaha, he carefully worked out a table showing the number of cars his engines would haul on different grades, in which he has even taken into consideration the effect of the wind on his train moving at a given velocity; below is a table giving Mr. Seymour's loads in cars on grades from 10 to 80 ft., and opposite, the numbers of cars given by the above equation, discarding from it the weight of the engine:

Grades.	Seymour's Report.		Formula.	
Feet.	Cars.	Differences.	Cars.	Differences.
0	94		94	
		38		36
10	56		58	
		16		16
20	40		42	
		9⅓		9⅓
30	30⅓		32⅓	
		5⅓		5⅓
40	25		27	
		4⅓		4
50	20⅓		23	
		3⅓		3⅓
60	17		19⅓	
		2		2⅓
70	15		17	
		2		2⅓
80	13		15⅓	

By this table it will be observed that the differences between Mr. Seymour's figures, which are accepted as accurate, and those given by the formula, are nearly alike; and, therefore, the calculated values of any modification of grade from either column will be almost identical for any grade less than 100 ft. per mile.

Substitute in the expression of the annual cost of the motive power in dollars, $\frac{4\,W}{5\,A}$, the value of A, just found, and it becomes $\frac{16+X}{20\,T}\,W$. Now, if X assume a new value, X^1, the difference in cost of motive power between the two grades will be

$$\frac{16+X^1}{20\,T}\,W - \frac{16+X}{20\,T}\,W = \frac{X^1 - X}{20\,T}\,W.$$

For application, let $X^1 - X = 1$, then $\frac{W}{20\,T}$ will be the increment in the annual working cost for each foot of the grade.

As an example—assume 940 tons, the load which Mr. Seymour takes as the gross load an engine can draw on a level on his road, then $\frac{W}{20\ T} = \frac{W}{18{,}800}$; capitalize this (money taken at 7 per cent.), and $\frac{1}{18{,}800} \times \frac{100}{7} = \frac{1}{1{,}316}$ of a dollar will be the value per ton per mile for each foot taken from the ruling grade. The engine stage west of Omaha is reported to be 145 miles long, and it is presumed that this is found to be the economical run for the engine; if Mr. Seymour's figures, 112,800 tons, for the probable business to be done against the heavy grade, are taken as the gross tonnage conveyed through in the direction of the grade, the sum one would be justified in spending to reduce the grade 10 ft., will be $\frac{112{,}800 \times 145 \times 10}{1{,}316} = \$124{,}286.$

Mr. Wilson Crosby—The line on the Union Pacific Railroad, between Omaha and the Elkhorn river, as at first adopted, showed grades of 66 ft. per mile, ascending westward in two instances, and 80 ft. per mile ascending eastward in three instances; and so distributed that the engine power required to work this part of the road would practically have to run over the whole distance between Omaha and the Elkhorn, 23 miles.* By this formula the value of a reduction of 10 ft. in the ruling grade with the assumed movement of 112,800 tons against it annually, would be

$$\frac{112{,}800 \times 23 \times 10}{1{,}316} = \$19{,}714$$

instead of $124,286, obtained by supposing the engines to all run a distance of 145 miles west of Omaha. If the grades were made to conform to 30 ft. per mile rising west beyond the Elkhorn river, the amount of expenditure justifiable to accomplish this then would be

$$\frac{112{,}809 \times 23 \times (66-30)}{1{,}316} = \$70{,}971.$$

* West of Elkhorn the grades were level, or ascending gently westward. As the idea of reducing the grades between Omaha and the Elkhorn to 30 ft. per mile was entertained, it is presumable that those in the Plate Valley did not exceed this limit, and that 30 ft. per mile, rising west, may be taken as the rolling grade on all except the section between Omaha and the Elkhorn.

The annual business to be anticipated when converted into freight car-loads, according to Mr. Seymour's standard, gives 45,000 car-loads westward and 34,700 car-loads eastward (including the return of empty cars). By reference to the table it will be seen that an amount of force capable of transporting 45,000 car-loads up grades of 66 ft. per mile, will be more than sufficient to haul 31,700 car-loads in the opposite direction up grades of 80 ft. per mile. For this proportion of traffic 39 ft. per mile ascending east would be an equivalent to 30 ft. ascending west. The 66 ft. rising west is the ruling grade on this part of the road as located originally.

IRON AND STEEL INSTITUTE.

PRESIDENT ISAAC LOWTHIAN BELL'S ADDRESS.

Responding to an invitation of unmistakable cordiality, the Institute held its last meeting at Liége. The terms of the request that we should visit our Belgian friends justified great expectations, but these fell far short of the actual arrangements made for our reception. On arriving at this important seat of the Continental iron trade, the military and municipal authorities of the town assembled to do honor to the British representatives of an industry so peculiarly its own. Private as well as public hospitality did their utmost to render our sojourn one continuous festival, and this of so attractive a nature that it may be doubted whether the more severe labors of the Institute were not, in consequence, somewhat neglected. It could not, however, fail to be highly agreeable, as well as instructive, to have an opportunity of observing that the same spirit of frank communication of ideas which marks our intercourse with each other met us at every turn on the banks of the Meuse. The office of assuring us of the pleasure our presence afforded all classes of the community was undertaken by gentlemen distinguished in science or art, and our expedition to Belgium was one of the rare, if not the only occasion, where the sovereign of a country identified himself with his people in offering a genuine welcome to so numerous an embassy of peace. Those of our body who had the opportunity of enjoying the magnificent hospitality of his Majesty the King of the Belgians, will understand and appreciate the nature of the union which binds that enlightened monarch with subjects whose labors, like our own, combine individual prosperity with national progress.

At this, the commencement of another session, I have been induced, at the suggestion of certain members of our Council, to submit to this meeting a few matters of general interest to those engaged in the manufacture of iron in its different stages. This idea arose, in the first instance, from a natural wish to receive some information on the extent of the progress which had been made in mechanical puddling.

It will be in the recollection of all, that, at our Dudley meeting, a paper was read on this interesting subject by Mr. Samuel Danks. The account he gave of the success, in the United States, of the revolving furnace which bears his name, was such that, under the auspices of the Institute, a Commission was sent across the Atlantic to judge from personal examination of the performance of this invention. Moreover, in order to test the stability of the Danks furnace for puddling the iron of this country, quantities of pig from different localities were sent out to be operated upon in presence of the gentlemen who had to report upon the mode in which it effected its duty.

In all respects, the accounts received from our commissioners were so satisfactory that certain firms made arrangements for giving the system a proper trial in this country. These were:—

Messrs. Bolckow, Vaughan & Company, Limited, Middlesbrough, who speedily had two experimental furnaces in operation.

Messrs. Hopkins, Gilkes & Company, Limited, by whom has been erected a complete forge, comprising two melting cupolas, twelve revolving furnaces with powerful shingling machine, and a set of three-high rolls for reducing the blooms into bars.

The Erimus Iron Company, also at Middlesbrough, who have built a complete forge, consisting of twelve furnaces, to which is now being added a finishing mill for working up the product into merchantable iron.

The North of England Industrial Iron Company, at their works, near Stockton, erected a forge consisting of eight furnaces with the requisite machinery for obtaining puddled bars.

In addition to these establishments on the Tees or its neighborhood, Mr. Robert Heath has constructed six furnaces in North Staffordshire.

It is not my intention to go into any details of the actual results which have been obtained at the various establishments in which the trials themselves have been made; at the same time, I feel sure that every one present will most thankfully receive any information with which those possessing, and authorized to communicate it, may favor the meeting.

As the preliminary investigation, however, into the merits of the Danks furnace was undertaken at the instance of the Institute itself, I deemed it my duty, in the absence of other communication on the subject, to make some inquiry into what had up to this time been done. I did this in the hope that, when I brought it before you, some gentlemen would avail themselves of the opportunity by stating their opinion of what we might expect from the proposed supersession of the more laborious part of the puddling process by mechanical agency.

Speaking generally, then, I may be allowed to observe that at no previous period in the history of the iron trade would this change have been more welcome than during that which intervened between the meeting in 1871, when Mr. Danks read his paper, and the present time. For a considerable portion of it, not only have we had the price of labor rising to a point hitherto unknown in the industrial annals of this country, but there was an actual want of the necessary human aid to meet the extraordinary demand made on our malleable ironworks for their produce. Within the last few months, however, a great change has taken the place of previous prosperity; but, in a commercial sense, we require, perhaps more urgently than ever, any relief which mechanical puddling can afford in a manufacture which all but, and in some cases perhaps, has ceased to be profitable, and in which serious difficulties are more than apprehended.

I fear, notwithstanding, it must be admitted that the success which has attended the substitution in this country of the new for the old plan of hand-puddling, has not invariably corresponded with the accounts given us by those gentlemen who reported upon its introduction in the United States. Nevertheless, I would not have it supposed that I am impugning in any degree the soundness of their observations while engaged in their mission. It is quite possible that American iron may offer less difficulties while under treatment in a Danks furnace than that of this country. It is also equally possible that those difficulties

which have been encountered in a continuous application of iron, such as that produced in Cleveland, may not have been so apparent when treated in more limited quantities during the comparatively short trials made under the personal superintendence of our Commissioners.

Referring, now, more particularly to the North of England, I have to observe that some alterations have even been found necessary in the moving, as well as in other portions of the machinery. These minor defects, so far as I can learn, have been overcome, and there remains the one great impediment to success, upon which, at Dudley, so much stress was laid, viz., the durability of the lining of the furnace. Upon this branch of the question, the testimony obtained in the North of England is somewhat conflicting. At one establishment, the entire plant, after some months of work, has been laid idle, and preparations are there in progress to alter the furnaces to the plan recommended and already described by Mr. Crampton, in a paper read before the Institute. On the other hand, while admitting the existence of difficulties not yet entirely vanquished, the practical men who are directing the trials express themselves confident of ultimate success.

In the puddling process, as it is generally understood, we seek to remove the substances usually associated with iron in the pig, such as silicon, sulphur, phosphorus, and carbon, by oxidation, either direct by the atmosphere, or more probably by a conversion of a portion of the iron into an oxide, which, in its turn, reacts upon substances which are well known to exercise a prejudicial influence on the properties of the metal in its malleable form. The presence of the carbon constitutes, of course, the only essential difference between cast and wrought iron, and it is possible to remove this element before the other three named substances are fully oxidized. In such a case, we will have them in greater or less quantity in the precipitated malleable iron, from which no subsequent treatment can effectually free them. Hence, no doubt, the variations observed in the quality of the product; for the strength and efficiency of the best puddler will fluctuate in so laborious an occupation as that in which he is engaged.

By the use of machinery, all irregularity in the character of the manipulation to which the iron is exposed may be avoided. Again, the use of large quantities of ore, sometimes amounting to half the weight of the metal, is probably beneficial. Certain it is that all experimenters with the Danks furnace concur in asserting the product obtained to be of superior excellence compared with the ordinary run of iron made in the furnace worked by manual labor.

There is another circumstance in connection with the manufacture, as it has been hitherto pursued, which possesses certain disadvantages. When iron of high tensile power is required, no one disputes the value of "work," as it is termed, consisting of drawing out to as great an extent as possible by the rolls, the iron under treatment. It is very questionable, however, whether any good arises from this mode of dealing with a material which has to form an object exposed to friction, and in which resistance to abrasion has to be guarded against. In such we may have a wearing surface, like that of a rail, composed of the original puddled bars, elongated until they probably do not exceed $\frac{1}{20}$ of an inch in thickness, more or less imperfectly welded. I say imperfectly welded, because there seems little doubt that the interposition of an excessive amount of the fused oxide of iron, or cinder produced in the balling furnace, offers a considerable impediment to complete union. This cinder, being imprisoned in the substance of the iron, is the origin of the occasional well-known exfoliation of the rail, from which steel, owing to the homogeneity of its texture, is entirely exempt.

Mechanical puddling, then, affords the means not only of securing iron of an improved and regular quality, but the power it commands of manipulating the metal in masses beyond the compass of human exertion will, in my opinion, tend to place an iron rail in a position more nearly approaching to one of steel. With such prospects, it cannot be doubted that our Institute did wisely in drawing the attention of manufacturers to the Danks furnace, and will act prudently in continuing to encourage every attempt to overcome those difficulties which almost invariably beset the introduction of new inventions.

Considerable importance is attached, and fairly so, to the superior yield afforded by mechanical puddling as compared with that performed by manual labor. I would point out, however, that this is secured at a certain sacrifice, for in no case do I find that

the large quantity of ore, containing 50 or 60 per cent. of iron, affords above 20; while, on the other hand, a large quantity of additional material has to be maintained for a considerable time at a very high temperature.

Those members who took part in the meeting held in London, in April of last year, will remember a paper by Dr. Siemens, which excited much attention at the time, "On the Manufacture of Iron and Steel by Direct Process." The information contained in it possessed much interest, not only in a commercial, but in a scientific point of view. We had described to us a furnace having the power of commanding a most intense temperature, with the novelty of the fuel, as a gas, entering, and the products of combustion leaving, by the same aperture. I have no doubt the Institute would be glad to hear whether this ingenious adaptation of the regenerative furnace, as applied to ordinary puddling, continues to afford the satisfactory results described as being obtained by Messrs. Nettleford and Chamberlain.

It would be useless to detain the meeting at any length with what are the admitted defects of the blast furnace, so far as an imperfect combustion of the fuel and the absorption by impurities and consequent deterioration of the resulting iron are concerned. Looking at what takes place in the puddling furnace, it seems reasonable to suppose that the phosphorus and sulphur, being always in the presence of more or less oxide of iron, in this direct process may never, or at all events to a much less extent, pass over to the metal.

The merit claimed by Dr. Siemens, in respect to economy of fuel to the amount he names, I must confess, stands, in my judgment, on more debatable ground. It is contended by him that the products of combustion escape from the blast furnace chiefly as carbonic oxide, at a temperature of 350 deg. C. (662 deg. F.), and that complete combustion is impossible, because each atom of carbonic acid would immediately split up into two atoms of carbonic oxide, by taking another equivalent of carbon from the coke present. It must, however, be remembered that this reaction would have to be effected in a region of the furnace where the temperature is insufficient for its accomplishment; that $\frac{1}{3}$, or thereabouts, of the fuel, does actually escape as carbonic acid, affording the full measure of heat carbon is capable of producing, and that the real barrier to its more complete combustion is the inertness, in a properly constructed furnace, of the resulting gases on the ore under treatment. Dr. Siemens does not, of course, deny the antagonistic action of carbonic acid on metallic iron; but he expects to avoid this, as well as the reduction of this carbonic acid to carbonic oxide, by exposing the fused ore to the influence of solid carbon. In this way carbonic oxide, he states, is alone produced, and then that this carbonic oxide is burnt to carbonic acid, where it meets with no carbon to split it up.

If the system propounded to us last spring admits of these conditions being fulfilled, I am ready to allow an excellent yield of metal from the ore will, in all probability, follow. I see, however, much practical difficulty in securing a state of things which I believe essential for commanding even an approximation to complete reduction of an oxide of iron.

After allowing sufficient margin, the consumption of fuel is put down at 25 cwt. per ton of iron; but conceding the perfect combustion calculated on, my own expectations are less sanguine than those of the author of the paper we are considering. No doubt, he deprives the gases escaping from his regenerator of more of their sensible heat than happens in the blast furnace; but, as I have formerly pointed out, the blast furnace does satisfactorily account for the appropriation of all the heat evolved, and, of this heat, the waste scarcely exceeds 15 per cent. In the regenerative furnace, on the other hand, we have to deal with a contrivance where a large preliminary loss has to be encountered in the "producers," and then the gas therein generated has to be burnt in a reverberatory furnace, from which, according to the experiments of Professor Krans, only 17 per cent. of real effect is obtained.

Whatever may be the ultimate destiny of the direct process as described by our colleague, I, for one, am grateful to him for the valuable information he has acquired, and communicated to us, in his experiments on the reduction of iron ore in the furnace which is known by his name. In my first address from this chair, I called attention to the immense service likely to be rendered by the regenerative furnace in the manufacture of steel, of which commodity the weight annually produced has since then

reached the important figure of 250,000 tons.

Owing to the conditions attending its production, there is no metal more liable to be contaminated by foreign matter, and none more sensitive to the influence of such foreign matter, than iron. One or two-tenths of carbon per cent. may impair its malleability, and a little above the ten-thousandth part of phosphorus, more or less, may constitute the difference between steel being manageable in its manufacture, or the reverse. On the other hand, phosphorus may exist in bar-iron, and even improve its facility of manipulation in the rolling mill, while its presence in far less quantity renders steel entirely useless. Carbon and phosphorus may then be combined separately with iron, of course, in very minute quantities, without serious injury to the product; but the question has been raised lately by M. Euverte, of Terrenoire, whether it is not the concurrent presence of these elements which exercises so fatal an effect on the quality of steel.

When Mr. Bessemer first tried to apply his steel to the production of a railway bar, his attempts in many, indeed in most cases, were unsuccessful. Subsequent investigation made it appear that the passage of so large a body of air through the melted pig, as is requisite to decarburize the iron, leaves a quantity of oxygen, either combined with, or occluded in, the iron. To remove this, a certain quantity of spiegel is added, the manganese of which absorbs and removes the oxygen as an oxide. The spiegel is thus used as the vehicle of recarburization, for, in removing the oxygen absorbed in the converter, carbon at the same time is added. M. Euverte points out that the employment of 7 cwt. of spiegel, containing 9 per cent. of manganese and 5 per cent. of carbon, to 3½ tons of Bessemer steel, gives an excess of carbon; and if less spiegel is used, the deficiency of manganese interferes with the malleability of the product. By means, however, of the substance known as ferro-manganese, which is manufactured commercially containing as much as 75 per cent. of the last-named metal, this difficulty is avoided. By its aid, M. Euverte expresses the utmost confidence in being able to declare, as a natural law, that we may introduce phosphorus into cast steel, provided carbon is eliminated, and that the less carbon, the more phosphorus may be present.

This French metallurgist does not pretend that we are entitled to infer that steels containing phosphorus are as good as those free from it; on the contrary, he recommends the use of materials containing the smallest quantity of this ingredient. Inasmuch, however, as we now possess the means of fusing wrought iron, and the presence of phosphorus—in moderate quantities, at all events—is declared by M. Euverte not to interfere with its malleability under the rolls, I have deemed the subject worthy of being brought under your notice.

The enormous advance in the market value of coal in all parts of the kingdom has invested every question relating to its economy in our various operations with the deepest importance. In the case of the blast furnace, this importance has been intensified—certainly in the North of England—not only by the unheard-of price which coke attained, but from an absolute scarcity of the article. Under the double inconvenience as to price and supply, we may regard every hundredweight of fuel per ton of iron unnecessarily consumed to have entailed a loss of two shillings, while the inability of the manufacturer to obtain this quantity diminished his make to the extent of nearly 5 per cent., and this during a period of almost unparalleled prosperity.

It is needless to say that any chance of relief, from whatever quarter it might have proceeded, was watched with much anxiety, and the possibility that superheated blast might do something in this direction, has conferred upon the fire-brick stoves a position of unusual interest.

It is some time since the subject of additional temperature in the air used in iron smelting has been before us, and, therefore, perhaps I may be allowed to say a few words on the views which have been expressed at some of our early meetings.

It was admitted on all sides that when hot air was first applied to the blast furnace, the economy of fuel far exceeded the heating power of the coal burnt in the apparatus suggested by Neilson. This result, later on, gave rise to an expectation that by every increase in the temperature of the air an economy corresponding to some extent to that first obtained would be realized. I have endeavored upon former occasions to demonstrate that the apparently inexplicable action of the hot blast was due to what was equivalent to an enlargement in

the size of the furnace. This was effected by a substitution of heat alone for heat accompanied by the products of the combustion by which it was evolved, so that, for a given quantity of heat produced, the reducing gas had, by its diminution of volume, a prolonged, and, therefore, a better opportunity of performing its office. Actual experience has confirmed this explanation, for precisely the same effects have in one instance been produced as were obtained by the use of heated air. This point in regard to capacity reached, it has been my study to prove that all additions to the temperature of the air have no more value in regard to effect than the same quantity of heat evolved by the combustion of the fuel in the furnace itself. True it is, that the nature of the combustion in a blast furnace is much less perfect than that which ordinarily takes place in the fireplaces of a hot-air stove; but against this we have the loss by escape of heat at the chimneys, radiation, etc., which numerous analyses and observations convince me is equal to half the value of the fuel consumed, while the actual waste in the blast furnace is only about one-third of this amount.

Commercially, therefore, it is only by having a fuel of much less value than that burnt in furnaces sufficiently capacious, say 12,000 to 15,000 cubic ft. and upwards, that we reap any advantage by a previous heating of the air before it reaches the tuyeres. Now, if we assume the power of a fire-brick stove to raise the temperature of the blast 500 deg. F. above that within the reach of cast-iron pipes, about 1¼ cwt. of coke is the utmost economy to be hoped for by the change, *i. e.*, provided my views on an identity of effect being produced by the combustion of the fuel in the furnace and that conveyed into its interior by the air used are correct.

Chemical reasons, to which I shall have occasion to allude, impose, in my opinion, useful limits, both as to size of furnace and temperature of blast; nevertheless, it is true that furnaces very much larger than the dimensions I have named continue to be built, and since we last discussed this somewhat complicate subject, many fire-brick stoves have been erected. I, therefore, invite any gentleman to communicate to this meeting his experience, which may justify a hope that any notable advantage is to be expected by a change in the construction of our furnaces or their adjuncts.

I have found an additional inducement in calling your attention to this interesting question, by a paper from the pen of my able and distinguished friend, Prof. Tunner. This communication has been translated and published in the last number of our "Transactions," and contains a criticism on the views I have propounded from time to time on the chemical action of the blast furnace. In particular, this learned metallurgist reminds me that the extent to which we can peroxidize the gases in the smelting process is greatly exceeded in the charcoal works of Styria and Carinthia. The subject here raised is one of great practical importance, for, in reality, upon it depends the existence of the useful limits of size of furnace and temperature of blast just alluded to.

My friend very properly admits that the law I have enunciated on the escaping gases, was confined to smelting Cleveland ironstone with coke; although I believe it is one equally applicable to most other ores where mineral fuel is used. Moreover, I did, towards the end of my work on iron smelting, call attention to the remarkable circumstance that, instead of 100 volumes of carbonic oxide being associated with 40 to 45 volumes of carbonic acid, these proportions were greatly exceeded at Eisenerz in the production of white iron from spathose ore. So doubtful was I of this, and so incredulous of the small quantity of fuel required, that Prof. Tunner, at my request, had the analysis of the gases repeated, and the performance of the furnace carefully noted. The results of this examination are given in his paper, from which it would appear a ton of white iron is obtained with 14 cwt. of charcoal, with the blast heated to only 300 deg. C. (572 F.), while the escaping gases give as much as 64 volumes of carbonic acid for every 100 volumes of carbonic oxide, or about one-half more than in any instance in my experiments. But here, again, there seems to be a limit beyond which oxidation cannot be carried, for we are told that, at Treibach, where the blast was only heated to 160 deg. to 200 deg. C. (320 to 390 deg. F.), it was doubtful whether any saving of fuel followed raising its temperature to 500 deg. C. (932 deg. F.)

In seeking for any explanation of the circumstances under which this kind of iron is thus obtained, with a consumption of fuel far below anything indicated in my own experience, I have to contend with the great

disadvantage of not having the action of a charcoal furnace to appeal to, and, in consequence, I offer an opinion on the subject with considerable reserve. My experiments, neither on spathose ore itself, nor on charcoal as a mere source of heat, lead me to think that they offer any solution to the apparent anomaly. Apart, however, from the carbon as it exists in charcoal, there is a point of dissimilarity, comparing it with coke, which is worthy of our notice. This consists in the much larger quantity of potash contained in the former, the presence of which is known to have the power of determining, at high temperatures, the union of nitrogen with carbon, and so form cyanogen. I have shown that, even in a coke furnace, owing to the condensation of this alkali in its upper region, a vast accumulation of cyanides takes place during the process of smelting. It will, therefore, only be reasonable to suppose that, inasmuch as charcoal contains a larger proportion of potash than coke, those cyanogen salts may exist in larger quantities in the furnaces examined by Prof. Tunner than in those of the North of England.

Carbonic oxide is the ordinary form in which carbon reduces iron in the blast furnace, and when one-third, or thereabouts, of a given quantity of this substance, as it exists in carbonic oxide, is converted into carbonic acid by the operation, all further action ceases. Before a similar saturation of the gases with oxygen has taken place, when the carbon is presented in the form of cyanogen, three times as much oxide of iron will have been reduced as when this agent exists as carbonic oxide.

This reasoning led me to institute a number of experiments on the behavior of cyanogen, in the presence of carbonic acid, on oxide of iron, and then to compare the results with those observed on mixtures of carbonic oxide and carbonic acid.

I found formerly, that when equal volumes of the two last-mentioned gases were passed over reduced iron at a red heat, the metal was oxidized. I also ascertained that, when oxide of iron, or ores of iron, were similarly exposed, they lost oxygen until they had a composition corresponding to protoxide. Such a mixture of these oxides of carbon is, therefore, essentially of a non-reducing description.

I have, upon previous occasions, spoken of what is in all probability an important action in the blast furnace, viz., the power of iron and its oxide to split up carbonic oxide into carbon and carbonic acid, which was described as carbon deposition or impregnation. It was found that at no temperature was carbon deposited from carbonic oxide when the mixture of gases consisted of equal volumes of carbonic acid and carbonic oxide. Indeed, the phenomenon disappeared soon after increasing the proportion of carbonic acid to one-half the volume of carbonic oxide.

Cyanogen and carbonic acid were experimented on in the proportion of one volume to six, because the relation of carbon to oxygen in such a mixture is the same as in equal volumes of carbonic oxide and carbonic acid. It was first ascertained that the mixture was unaffected by a mere exposure to heat, after which it was passed over oxide of iron at a temperature of redness for $2\frac{3}{4}$ hours. After this time the result was found to contain:—

Metallic iron		40.9
Iron combined with oxygen	31.8	
Oxygen	6.7	38.5
Carbon		20.6
		100

thus showing that reduction and carbon deposition had taken place to a large extent.

Professor Tunner proceeds to show that by raising the temperature of the blast from 200 deg. C. (392 F.), to 500 deg. C. (932 F.), the consumption of charcoal for grey iron was reduced from 23 or 24 cwt. to 19 or 20 cwt. No particulars of the composition of the gases are given, but, looking at the richness of the ore and the heat units required for its production (58,800 instead of 93,000, as in Cleveland), I feel sure the relation of carbonic acid to carbonic oxide in the escaping gases will be below that I have observed in the Middlesbrough district. It seems, therefore, possible that the high temperature indispensable for obtaining grey iron is unfavorable for the accumulation of cyanogen compounds, and hence as complete a saturation of the gases by oxygen is impracticable in the small furnaces of Styria and Carinthia, as when white iron is the object in view.

Recently, unmerited prominence, in my opinion, has been given in the "Times" newspaper to a so-called proposal to substitute chalk for coal as a source of heat. Within the last few weeks, this journal states with some emphasis, "that the ap-

plication of chalk as fuel being attended with satisfactory results has been proved by figures." This is attempted to be shown by comparing the expense of heating a church during two winters, upon one occasion with coal alone, and upon the other with a mixture of coal and chalk, and the extent of the saving is given at 50 per cent. In these figures, not a word is said of the actual rise in the temperature of the atmosphere of the building, so that the proof itself is most incomplete. I will not pretend that the heating arrangements of the church being defective, some advantage may not have been derived, although I think it unlikely, from the addition of chalk; but that the splitting up of the component parts of this substance can have otherwise than a cooling effect, is too apparent to need comment.

If there were anything in the proposal, what are the directors of the railways near London about? They are still bringing fuel from the North of England for engines which are running through a country, the entire surface of which is composed of a mineral possessing, it is said, when used with fuel, an equal heating power. Until this or some analogous exact trial is made, the inventor will have some difficulty in persuading an ironmaster to adopt his scheme for smelting, knowing, as the latter does, that he saves fuel by a preliminary calcination of the limestone he is compelled to use as a flux.

Questions of a purely trade nature do not come within the sphere of our discussion, save when the same are effected by changes in the machinery we employ, or in the processes themselves. The extraordinary nature of the fluctuation in the value of our produce, which has made itself felt within the last few months, is such as to have assumed the dimensions of a subject of national importance. This must be admitted, when we reflect that the depreciation of price in the annual production of the furnaces and mills of this country cannot be short of £20,000,000. The decline in price, although not unexpected, has been so rapid that neither employers nor men have had time to accommodate themselves to the altered state of things, and sounds of violent alarm are not uncommon as to the future of this great branch of our national industry. Fears are again expressed that some of the ironmaking States of Europe are ready to seize and retain a trade which has, in a peculiar degree, been regarded as our own. Belgium, in particular, is represented as the source of our greatest danger, and a French minister is said to have declared that France is now able to compete with England in the manufacture of iron. No one thoroughly acquainted with the natural resources of these countries, or with those of Germany, as they now stand, can imagine that there is any real ground for believing that we can be permanently disabled in our competition with any of these nations. It has been publicly announced that bar iron in some quantities has been imported into this country from Belgium. Granting this to be so, what lasting impression can that country produce on our trade, supplied, as the latter is, by 7,000 to 8,000 puddling furnaces, against less than $\frac{1}{10}$ of this number of this foreign State? Even in the matter of ore, the Belgian mines have greatly receded in their output during the last ten years, while their importations from France and other places have greatly increased. On the other hand, the quantity of pig iron sent out of this country to Belgium is 17 times what it was in 1863. But the obvious limit to such an expansion of the Continental iron trade, as seriously to threaten our position, is an actual want of sufficient coal to make the iron now being turned out of the works of this country. No doubt one great inconvenience of such an inflated state of trade as that which recently manifested itself in our particular branch, is the stimulus it affords to competition—foreign as well as domestic. Under its influence, the United States of America, in the production of iron, have advanced at a rate unknown in their previous history, and, as a consequence, the importation of rails from this country has materially declined. Our own workmen considered themselves entitled, and reasonably so, to a participation in the high prices which recently prevailed, and, naturally, they regard with little favor that change which the present state of affairs renders inevitable.

Whatever difficulty may beset us at the present moment, it can only be of a temporary character. Of raw materials we have an abundance; of our skill as manufacturers, whatever may be said to the contrary, we have no reason to be ashamed; and it will be a strange thing if, with these advantages, British energy is unable to hold its own against any people in the world.

USEFUL DISPLACEMENT OF SHIPS AS LIMITED BY WEIGHT OF STRUCTURE AND OF PROPULSIVE POWER.*

By WILLIAM FROUDE, Esq., F. R. S., Vice-President.

From "Iron."

It seems a mere truism to state that the best ship for the performance of a given duty is that in which the useful displacement bears the largest proportion to the whole displacement; yet I believe that this aspect of a ship's merits has not been as systematically investigated as it deserves, or as it is capable of being investigated. Stating the proposition broadly, and with a view to the approximate and incomplete character of the following investigation, it is not necessary to define minutely the sense in which the term *useful displacement* will be used. It is enough to regard it as that displacement which remains after deducting the dead weight (1) of the hull as completed with proper regard to structural strength, and (2) of the engine power necessary to drive the ship at the required speed, together with the coal which will be consumed on the voyage. As, however, the coal consumed per day will be approximately proportioned to the engine power, while the coal per voyage will depend upon the length of the voyage, the question whether capacity for coal should be counted as part of the useful displacement, or whether the coal carried should be regarded as dead weight, will depend on whether the merits of the ship are viewed generally, or in relation to a particular voyage.

I ought to state at starting that when the problem is treated thus broadly, and to the exclusion of such limiting conditions as are imposed, for instance, by the necessity of traversing the Suez Canal, its investigation points to the conclusion that the existing tendency towards great length, as compared with beam or with area of midship section, is only justified where extreme speed is required, speed very much greater than that which sea-going merchant ships in fact realize. My object, however, is not so much to enforce the conclusions which I have myself arrived at, as to endeavor to induce those members of the institution whose long experience and mature judgment is essential to the complete solution of the problem, to co-operate in the endeavor to arrive at something like a general, even if it be but a provisional solution of it, or at all events to see whether some very instructive and useful results cannot be arrived at, by treating it in virtue of the larger principles which underlie it; leaving for subsequent introduction those modifying peculiarities which, unduly indeed, yet not without plausibility, support the belief that every case is a special case.

Looking to the first of the two great divisions of the subject, that of dead weight due to structural strength, I am encouraged by recollecting the exhaustive and exact treatment which it received in one of its aspects, in Mr. Reed's well-known paper, which was read at the Royal Society, on "The Unequal Distribution of Weight and Support in Ships," as exemplified by the cases of the Minotaur, Northumberland, Bellerophon and Hercules. I am encouraged more by the completeness with which the principles of strain are there elucidated, than I am discouraged by the opinion to which Mr. Reed seems to incline, that it is not possible to reduce the problem to a complete general solution. For while granting fully that a *complete* general solution is impossible, it nevertheless appears to me clear that in proportion as we deal with larger and larger ships, the strains which have to be taken account of and provided for, become more exclusively those which are most amenable to calculation, and of which alone I propose to take cognizance—I mean what may be termed "sea-going strains."

In the paper which was read yesterday evening by Mr. John, the whole subject of the strains experienced by a ship in a seaway was so admirably treated, and was worked out with such quantitative exactness, based on data derived from actual ships, and far more complete than any that I possess, that I have thought it best to withdraw the detail matter I had prepared on that branch of the subject, and proceed to apply simply those fundamental principles which it appears to me must inevitably come into operation as governing the proportion of strain, and hence of structural weight, to dimension, taking Mr. John's results as a point of departure. For, if we

* From a Paper read before the Institute of Naval Architects by William Froude, Esq., F. R. S.

proceed from any one of the ships, the strains and strength of which he reduced to calculation, to a ship of the same type, but differently dimensioned, we can see very nearly how the strains and the structural weight in correspondence with them will vary in terms of the dimension.

First let us assume the length alone to vary, and let us suppose that the ship thus altered (we may for convenience say lengthened) to be subject to the operation of a proportionally lengthened wave. Then it is obvious that the volumes or weights inherent in the unequalized buoyancy which the wave creates, will be enlarged in the square of the ratio of elongation, since the areas which represent them in longitudinal section in the two cases will be similar areas, while the breadths will be the same in both cases; and since the leverage with which these volumes act in straining the ship will have also been enlarged in the ratio of the elongation, *the bending moment of the lengthened ship will be as the cube of the elongation.*

If we next assume the breadth of the ship alone to vary, it is plain that the straining weight will be enlarged in the simple ratio in which the breadth is enlarged, and the bending moment will follow the same ratio; since the leverage is unaltered, *the bending moment of the widened ship will be as the enlargement of breadth.*

Lastly, let the depth alone of the ship be assumed to vary; here it is plain that no variation of straining weight or of leverage will ensue; *the bending moment is independent of the depth.*

Finally, as regards the stress on the deck, and bottom and sides of the ship, regarded as the corresponding members of a box-girder, it is plain that in every case *the stress will be simply the bending moment divided by the depth of the ship*, and throwing all the conditions together, it follows that the stress on each member of the girder will be directly as the cube of the length, directly as the breadth, and inversely as the depth. The total sectional areas of the deck, the bottom and the sides must be proportional to the stress; and as the structural weight may be taken as proportioned to these sectional areas, multiplied by the ship's length, it must be regarded as proportional, directly to the fourth power of the length, directly to the breadth, and inversely to the depth. From this follows the remarkable result that, alike whether we enlarge a ship by increasing her three dimensions in the same given ratio throughout, so as to enlarge her displacement in the cube of that ratio, or by increasing her length alone, so as to enlarge her displacement in that ratio simply, the increase of structural weight will be as the fourth power of the enlargement of dimension. It is obvious that, in whatever degree the total dead weight of a ship's hull depends on her requirement for structural strength, this conclusion tells most unfavorably on the useful displacement of a ship enlarged simply by elongation, as compared with one enlarged in all her dimensions alike; nor can the question of first cost be unaffected by the same condition.

Turning next to the second of the two divisions of the subject—the dead weight of engine power regarded as a function of the dimensions—a full and exact general solution of this question cannot be arrived at without a more exactly detailed knowledge than we as yet possess of the law which governs resistance in terms of dimension, assuming each dimension to vary independently. Such a solution would require a knowledge of the "curve of resistance"* for the ship of each proportion. But though we do not yet possess this, I trust that the experiments I am conducting for the Admiralty will eventually supply it.

But if the ship is enlarged alike in all her dimensions, and if we know the curve of resistance for the original ship, the solution can be arrived at exactly, by a study of that single curve of resistance, or very approximately, in virtue of the "power" of the speed to which the resistance is seen to be proportional in the different parts of the curve; in either case, taking account also of the law of comparison, which, as I explained in the paper on the Greyhound, may be held to govern universally the ratio of the resistances of large and small ships built on the same model, if compared under the condition of what I have called "corresponding speeds." That "law of comparison" is that if the speeds of the ships are as the square roots of their respective dimensions, their resistances at those speeds will be as the cubes of their dimensions. The mathematical treatment of the question shows that if for speeds between a given

*That is, a curve in which, while the abscissæ express speeds, the corresponding ordinates express the resistances experienced by the ship at those speeds.

speed of the smaller ship, and the corresponding speed of the larger, the resistance of the smaller varies approximately as the power $(2+n)$ of the speed, the resistance of the large ship at the same speed as the small ship, will be that of the small ship enlarged in the ratio of the dimensional enlargement raised to the power $\left(2-\frac{n}{2}\right)$. From this it would follow that if the small ship were being driven up to a speed at which the resistance varied with the sixth power of the speed, the larger ship (if but moderately enlarged) would travel at the same speed as the small one without any increase of resistance.

I will here apply the comparison, as it would affect a ship of the Greyhound type if built of enlarged dimension. A careful examination of the curve of resistance shows that it is pretty exactly reducible to a succession of variations depending on the following powers of the speed:—

Power of Speed to which Resistance is Proportionate in "Greyhound."

	Knots.		Power.
From	0	to 5.5	2
"	5.5	to 9 5	2.5
At about	10.5		3.3
"	13.		4.5

Applying these figures in the manner described, we arrive at the following comparison between the resistances of the Greyhound and those of a larger ship of the same type, driven at the same speed. It will be observed that when the speed is the same for both ships, their horse powers will be simply proportioned to the resistance.

Growth of Horse-Power required for Constant Speed with Enlarged Dimensions.

Speed.	0. to 5 5	5.5 to 9.5	10 5	13
Power of speed to which resistance is proportional in original ship	2	2.5	3.3	4 5
Power of dimension to which resistance, or horse-power, is proportional in enlarged ship	2	1.75	1.35	0 75
Power of displacement to which resistance, or horse-power, is proportional in enlarged ship	0.67	.58	.45	0 25

It will be seen from this how very favorably the larger ship is circumstanced as regards engine power, if no enlargement of speed is contemplated. To trace out the result in connection with assumed increase of speed would lengthen the discussion inordinately.

With reference to the question of enlargement in one or other of the dimensions alone, if it consist of elongation alone, or of elongation accompanied by a relatively less enlargement in the other dimensions, though I am not in a position to tabulate the results, I feel confident that their general character would be as follows:—Assuming the typical ship to have, as most modern ships have, lines rather finer than the Greyhound, it is a mistake to suppose that, if she were simply elongated, this increased length would be unaccompanied by increase of resistance, at least unless probably such speeds as 13 knots were in contemplation. The increased surface friction inseparable from increased length, or rather from the corresponding increase of surface, inevitably produces an almost proportionally-enlarged resistance for a given speed. Now, as simple elongation has been shown to create a structural weight enlarged into the ratio of the fourth power of the elongation, while the displacement will only have been enlarged in the simple ratio of the displacement, and the engine power, and therefore engine dead weight, enlarged in nearly the same ratio, it is obvious that enlargement by elongation is, as regards useful displacement, wofully inferior to general enlargement, unless some very marked increase of speed is contemplated. I believe such ships could be made absolutely lighter if built with greater depth; and if the exigencies of the Suez Canal traffic require ships of small breadth and depth in immersed midship section, and therefore *prima facie* open to the objection I have been suggesting, it seems to me possible to meet the difficulty effectually and economically by giving greater depth amidships—adopting, in effect, something like the artificial girder structure adopted by the Americans in their long river and lake vessels, the height of freeboard, forward and aft, being regulated by the necessity of keeping the ship's ends dry, and the depth amidships being such as to meet the bending moment safely without excessive increase of structural weight.

THE PRESERVATION OF IRON STRUCTURES.

From "Iron."

Where great tenacity and toughness are not demanded, an iron containing a considerable proportion of silicon, carbon, and phosphorus, is preferable to iron of greater purity, and consequent higher price, provided always that it contains but little sulphur. The presence of much sulphur would probably neutralize the protective action of the other impurities, and I suspect that this has prevented the superiority of "bad iron" for certain uses from becoming practically understood. Every practical iron-worker can distinguish between ordinarily pure iron and that which is much less pure, but there are but few who are able to determine the source of the impurity. I strongly recommend the manufacturers of some of those brands of Cleveland pig which are comparatively free from sulphur, but are much depreciated in value on account of the phosphorus they contain, to make similar castings from theirs and higher-priced irons, and by exposing them equally to atmospheric action, compare the rate of corrosion of each.

If my theoretical anticipations are sound, the result of such trials will prove the superiority of these irons for many important purposes, such as cast water pipes, spouting, many kinds of ornamental work, etc.

The most obvious device for defending iron against surface corrosion is the coating it with some kind of adherent film, which is more or less capable of resisting atmospheric action. There are two distinct classes of such coverings—first, those which are dissolved in some liquid are applied cold, and slowly solidify by evaporation or chemical change; and second, those which are fused are applied hot, and solidify on cooling.

Of the first class the most common are paints and varnishes. These are so numerous that a separate examination of each would form a treatise in itself. I must, therefore, refer only in general terms to the properties of the most important. A paint consists of two chief components, the liquid medium and the solid body, the body being ultimately mixed, but not dissolved in the medium. Thus, in ordinary white paint, the body is carbonate of lead or "white lead," and the medium is linseed oil alone, or more commonly a mixture of linseed oil and turpentine. Turpentine is a volatile oil, *i. e.*, one of those oils which, when pure, evaporate away so entirely that if a piece of paper is wetted by them, and then exposed to the air, no film or stain is left behind. Therefore, if the body were mixed in pure turpentine, the paint would be worthless, as, on drying, the body would be left behind as a mere dry powder that could be readily brushed away. The use of the turpentine is merely to dilute the linseed oil, which is the true binding medium, and to hasten the drying, the paint being thinned or weakened in proportion to the quantity of turpentine that is used. It is important that this should be clearly understood by all who use ordinary paint for the protection of iron.

Linseed oil is quite different. It is a fixed oil, *i. e.*, it does not pass away by evaporation at ordinary temperatures, it cannot be boiled away nor distilled by heating it under ordinary atmospheric pressure, because its boiling point under such pressure is higher than its dissociation point, or the temperature at which it is decomposed by heat. But it does dry somehow; in this drying property it differs from ordinary fixed oils, such as olive oil, etc., and thus belongs to another subdivision of the fixed oils, viz., the "drying oils." How then does it dry if not by the ordinary process of evaporation, such as effects the drying of water, spirits, volatile oils, and most other liquids? This question is answered by the fact that it contains about 80 per cent. of a very curious liquid to which the name of linoleine has been given. This linoleine, when exposed to the air, slowly combines with oxygen, and is thereby converted into a solid substance of translucent resinous appearance, and possessing much of the toughness and elasticity of india-rubber or gutta-percha, though long exposure to light and a moderate degree of heat, such as that of the direct sun's rays, renders it harder and rather brittle. It is adhesive, remarkably impervious to water, and very difficult of solution either in essential oils, spirits, naphtha, or even bisulphide of carbon. Another important and valuable property of this linoleine is, that it expands in drying. This expansion is a simple result of its combination with oxygen, which increases both

its weight and bulk. The difference between a varnish and a paint may now be understood as it should be, for the distinction is not merely theoretical, but has some important practical bearings.

In varnishes the solid or body is *dissolved* in the medium, and the drying (with one or two exceptions, where a drying oil is the solvent) is effected by the evaporation of this medium. Gums, resins, or those intermediate vegetable products called "gum-resins," usually constitute the soluble solid of varnishes, and the medium is a volatile oil, spirit, or similar liquid. The solution forms an unctuous adhesive liquid which, when spread out, becomes, on drying, a solid resinous film.

It will be seen from this that there is a remarkable difference between the drying of a paint having the linoleine of drying oil for its medium, and the drying of a varnish, the medium of which is volatile, and dries by evaporation. In the latter there is a loss and *shrinkage* in drying; in the case of the lineoleine there is a gain (of oxygen) and an expansion. The importance of this, where the object is the protection of iron from corrosion, is very great, for the *shrinkage* of the resinous film of the varnish is liable to destroy its continuity, and form minute cracks through which atmospheric agents may reach the iron. This tendency to cracking is increased by the expansion and contraction to which metals are subject from variations of temperature. The thicker the layer of varnish the greater is the liability to cracking and peeling.

The reader who is well versed in metal work will probably object to this by quoting the common and successful use of a true varnish—viz., solution of gumlac or shellac in alcohol—for the lacquering or preservation of brass. But this same lacquer affords so little aid in the preservation of iron that, although it may be easily applied, it is very rarely used for the purpose of preserving iron or steel. This, I suspect, arises from the peculiar insinuating character of the oxidation of iron, due, as already explained, to the fact that the iron rust itself acts as an oxygen carrier. Every crack, pore or other flaw in the varnish, however small and invisible to the naked eye, becomes a centre of corrosion, from which the oxidation spreads downwards and radially, undermining all around. This undermining of the film is the more effective from the fact that the rust occupies a much greater bulk than the iron itself, and thus in swelling it must uplift and peel off the brittle film of shellac or other varnish, by a sort of microscopic eruption.

This inward spreading and undermining action of iron rust is the main source of the difficulty of protecting it by paints or varnishes. Even the continuous lineoleine film, in spite of its compactness, and the increased substantiability afforded by the body of the paint, gradually loses its toughness, curls up and peels off, revealing below a stratum of oxide which has somehow formed in spite of it. It is quite possible that the fully oxidized lineoleine may give up some of its oxygen to the iron surface which it covers. This idea is, however, purely speculative, as the subject does not appear to have been directly investigated.

The mechanical adhesion of the protecting film is, of course, a matter of primary importance. Certain substances are said to be "*sticky*," and this adhesiveness is very commonly regarded as an absolute quality. This is a great mistake. The adhesive affinities of any and every substance, whether solid, liquid or gaseous, vary according to the second body with which it comes in contact. If we take a common pair of scales, balance them, and then allow one of the pans to touch the surface of the water in a saucer, we shall find that it adheres to the surface of the water with considerable force. This force may be accurately measured by gradually adding weights to the other pan until the adhesion gives way, and the beam is tipped in the direction of the weighted pan. By varying the experiments and using flat discs instead of the pan, we may learn whether water adheres with equal or varying force to different solids.

The discs may be of, say, iron, steel, copper, tin, zinc, silver, brass, glass, etc.; if all are of the same shape and of equal size, and balanced before touching the water, the weight required respectively for effecting their detachment measures their respective forces of adhesion. These will be found to be curiously different. If we now acidulate the water, then make it alkaline, afterwards substitute it by alcohol, oils, ether, mercury, etc., we shall, with each substitution, obtain a new set of relative adhesive powers for each of our solid discs. The most remarkable differences will be found in comparing the adhesion of mer-

cury to iron with that to such metals as lead, tin, copper, etc.

Similar variations occur in the power of adhesion of the different films of which paints and varnishes may be composed, and it must be understood that in painting or varnishing a metallic surface, it is the adhesive force, pure and simple, that we have to depend upon. In painting wood or other porous material, the adhesion is aided by the fact that the paint penetrates the pores to a greater or lesser extent, and these extensions inward form minute rootlets by which the film is the more firmly held. If the film swells in drying, as in the case of the lineoleine, these roots become firmly wedged, and the paint is almost irremovable.

The practical question before us now assumes a definable shape. It becomes: What available film has the most complete continuity, or least porosity, and the strongest adhesion to iron, and is at the same time insoluble and impenetrable by the vapors and gases of the atmosphere? Here is a large and fruitful field for investigation, and one which has never been systematically tilled. We have only the random results of isolated, conflicting, and ill-recorded experience to guide us.

If I may venture to express an opinion founded on my own observation, which I do with much diffidence on account of its limited and desultory character, I should say that pitchy or bituminous films are especially effective as regards their adhesion to iron. Thus a solution of asphalt or pitch in petroleum or turpentine, leaves a strongly adherent film on drying. It is also very effective as regards its continuity, on account of its manner of drying. Instead of forming a hard and brittle scaly film, like most of the gum resins, the pitch film retains a certain degree of plasticity, which effectually prevents any cracking, and permits a yielding with the contraction and expansion of the iron. If the iron is at all rusty it penetrates the spongy surface of oxide and envelops the rust particles very effectively, holding them together and enlisting their services to form a portion of its paint body. Such a solution of pitch or asphalt may be regarded as something between a paint and a varnish, the pitch or asphalt being a resinous substance, and therefore by its solution forming a varnish; but it is not a pure resin, for it contains, and is colored by, minute solid particles of carbon, and these, of course, when diffused through the solution, correspond to the body of a paint.

Against these advantages there is one serious objection to a mere solution of pitch. It is to a certain extent soluble in water, and thus, when exposed to rain, the bituminous film is gradually washed away. This, however, may be remedied by mixing the solution of bitumen with linseed oil, or with a thin paint made by grinding red or white lead in linseed oil. I have tried this; I find it stand very well, and the experiment may easily be repeated by mixing about two parts of Brunswick black with one of ordinary white, red, or stone-colored paint, the body of which is composed of red or white lead, or litharge. Red lead is the best if well ground in. There are many kinds of bitumen that may be used, such as natural mineral asphalt, pine pitch, and artificial asphalt. There are two distinct varieties of the latter, differing materially in their properties. The first and most common is that which is left when the dead oil, etc., are distilled from common gas-tar; the second, the residue which is left when the spirit, lamp oil, lubricating oil, and solid paraffine are incompletely distilled from petroleum, or from the crude oil obtained by the distillation of cannel coal or bituminous shale. It is this which I recommend. It is easily obtained, and may be supplied in abundance from the neighborhood of Bathgate by the Scotch manufacturers of mineral oil. In order to obtain it in suitable condition for this purpose, the crude oil must be distilled before treatment with acid, and the final distillation stopped before the coking point is reached. By this means a hard bright pitch is obtained which contains a considerable body of carbon, and which is soluble in the unrefined or "once run" paraffine spirit, which itself is a mere drug in the market, and may be supplied at a very low price.

When I was engaged in distilling cannel at Leeswood, in Flintshire, I prepared a quantity of such paint, and used it very successfully for the preservation of both iron and wood. For such purposes as painting the hinges of cucumber frames, the hoops of water barrels, etc., I used it mixed with only a little boiled linseed oil, and without any further body than the pitch contains. When this sort of bitumen, which, for distinction sake, I will call paraffine pitch, is obtainable, no further admix-

ture than about one-half or one-third of its bulk of boiled oil to the solution in spirit is required.

About twelve months ago I was consulted respecting the means of cleaning and preserving a collection of very choice specimens of ornamental mediæval iron work intended for presentation to a provincial technological museum. They had been somewhat neglected and were already rusted. The problem to be solved was, to remove the rust without damaging the surface, and to prevent further corrosion without destroying the metallic tone of the surface or obliterating the sharpness of the fine ornamental work. The rust might have been at once removed by oxalic acid, but this and all other acids penetrate iron to a certain depth, and afterwards set up a new corrosion, however carefully they may be wiped or washed away. Therefore the use of any acid would have been ruinous. Painting over the surface in the ordinary way would have been downright Vandalism, worse than the church warden's mode of cleaning cathedral stone-work by whitewashing it. Ordinary oiling had been tried, but, though preferable to either of these, was not satisfactory. What, then, was to be done?

I obtained from a friend in Flintshire a sample of "once run" mineral oil, *i. e.*, paraffine oil that had been redistilled from the crude oil, but not yet washed with sulphuric acid. This oil contains sufficient free carbon to stain it with a brown tinge, but the particles of this carbon are so infinitesimally fine that their solidity is questionable—they may be regarded as carbon in actual or semi-solution.

This was sent to the gentleman, an amateur artist, who had charge of the specimens, with instructions that it should be first brushed smartly over the surface of the iron until all the rust disappeared, then wiped off and a second brushing applied lightly, and the surface left slightly and uniformly wetted with the oil. These instructions were ably carried out, and the result is reported to be very satisfactory. The rust was removed without violence, the rusted parts regained their natural color when wetted with the oil, and retained it after the oil dried. As the mineral oil is slowly volatile, this drying took place gradually, and an imperceptible film, due to the semi-dissolved carbon, remained behind, and protected the iron from further oxidation without in any degree damaging the tone of its surface. It will, of course, be understood that so delicate a film as this is only fitted for defending the iron from that degree of corrosion to which such carefully preserved specimens are liable. It has the advantage of being very easily applied, and may be repeated with any degree of frequency without damage, as each fresh brushing removes the previous film, as well as any rust or dirt that have subsequently invaded the surface.

Before leaving the paints and varnishes, a few words are due to a very humble and vulgar, but by no means uninteresting mode of protecting iron surfaces, viz., the housemaid's device of "black leading." In these days of general diffusion of chemical knowledge, it is scarcely necessary to state that the "black lead" or "plumbago" of commerce is not lead at all, nor any compound of lead, that it includes no lead whatever in its composition. Neither is it a carburet of iron, as is sometimes stated. It is simply carbon; pure plumbago is pure carbon, impure plumbago is impure carbon. Its proper name is graphite, *i. e.*, writing-stone. I may venture to describe it as the softest of all true solids, and have often pondered wonderingly upon the apparently unnoticed, but very curious chemico-mechanical paradox, that the hardest and softest of all the solids existing upon this earth are, chemically speaking, the same substance; graphite and the diamond being both carbon.

It is this wonderful softness, combined with persistent solidity, that enables us to smear it over any other solid surface, and thus obtain a *solid paint*, all body and no medium. For the class of castings to which it is commonly applied, where its application can be readily repeated, and where it is not exposed to the direct action of water, it is unrivalled as a protecting film to iron. Its chemical action, so far as it does act when cold, is reducing or anti-oxidizing. Its color and tone are so similar to iron that Mr. Ruskin himself could scarcely make any æsthetic objections to its use, and the film is so marvellously thin that it obliterates nothing. I have never met with any attempt to estimate the thickness of a well-brushed film of graphite, but I suspect that if a hundred strata of such films could be piled in actual contact with each other, their combined thickness would fall short of that of the thinnest gold leaf. I base this esti-

mate upon what I have observed in using it for purposes of electro-deposition. The chemist, therefore, can give but little aid to the housemaid in this matter, he can only explain and admire her practical discovery.

The application of protective films by means of fusion, next claims attention. Tinning, and the process to which the absurd name of "galvanizing" has been applied, are the most prominent of these. The principle and practice of the mode of application is the same in both, though the material of the protecting agent is different, zinc being used in the place of tin for the latter process.

In both cases the iron surface is made chemically clean. This is effected by the combined action of mechanical scrubbing and chemical "pickle." The pickle used is hydrochloric acid for galvanizing, and the same with or without a second pickle of sulphuric acid for tinning. The iron thus cleaned is either dipped in a bath of melted tin or zinc, or the melted metal is brushed over it. The dipping is the best, and is used where applicable, care being taken to brush or drain off the excess of adherent fused zinc or tin. It would be out of place here to describe the many precautions necessary to conduct these processes effectively and economically. A considerable amount of skill is demanded, especially in tinning.

This demand for skill, as well as the effectiveness of the protection afforded to the iron, depends on the fact that the tin or zinc is not merely painted over the surface of the iron, but that an actual alloy or amalgam is formed, which extends to some depth below the surface. This is shown by placing a thick piece of iron in a tinning or galvanizing bath, leaving it there for some time, and then breaking or cutting it through. The fracture or section shows that the zinc or tin has penetrated to a measurable depth below the surface, and this depth increases with the time of immersion; thus it is very easy to tin or galvanize a piece of iron completely throughout. Such a piece, on being filed or otherwise worked, presents all the appearance and properties of a true alloy.

In the ordinary course of tinning and galvanizing, the cost of the tin and zinc, especially the former, being considerable, the iron is only immersed sufficiently to insure a complete surface covering, with as little penetration or internal alloying as possible. This fact seriously limits the value of this mode of protecting iron. As we all know, both tinned and galvanized vessels used for containing water begin to rust after a certain length of time, and as the skill of the tinner in economizing material increases, the durability of his work diminishes.

I think that some of our enterprising manufacturers would do well to consider whether it would pay to bring out a new class of tinned and galvanized goods, the tin or zinc of which should be guaranteed to have penetrated bodily through the iron. For many purposes this would be very desirable. Such an alloy would be almost imperishable. As zinc is so much cheaper than tin, and appears to penetrate iron more readily, it is in the direction of galvanizing that this suggestion might be more readily carried out.

The influence of such a soaking of iron and steel with a foreign metal upon its tenacity suggests a very interesting subject for investigation. Is the metal of inferior tenacity so alloyed or combined with the more tenacious iron as to form a compound of intermediate tenacity? Or does the penetrating metal merely soak itself into the pores of the iron or steel, and thus solder together the fibres, crystals or granules, and increase their tenacity? These are fair questions, and worthy of experimental reply.

The protective effectiveness of tinning and galvanizing is unquestionable, but their applications are necessarily limited to small ironwork and utensils. Structural iron can receive but little aid from them. Another limitation is due to the fact that iron of a very superior quality and unblemished surface is required. For tin plates, charcoal iron is commonly used, and even this is subject to failure from the accidental presence of cinder on the surface of the plate. All plates and sheets rolled from puddled iron are subject to this defect, however great may be the care that is used in their manufacture.

There is another mode of protecting iron, viz., by coating it with lead by means similar to those used in tinning and galvanizing. Such leaded iron is utterly unfit to supersede tin plate for culinary utensils, as all soluble compounds of lead are poisonous, and are the most treacherous of poisons, as they act by gradual accumulation. The danger is increased by the fact that acetic acid or vinegar, dissolves lead so readily,

and this acid may be formed accidentally by the fermentation of substances commonly used for food.

For many purposes, such as roofing, spouting, etc., wherever zinc is commonly used as a substitute for sheet lead, this leaded sheet iron may be very useful, and I think deserves more attention than it has yet received. I used it successfully about eight years ago at Leeswood, in Flintshire, for the construction of condensers attached to retorts, in which cannel and shale were distilled for their liquid and solid hydrocarbons. These condensers were upright cylinders standing out in the open air, and cooling by radiation.

Many attempts have been made to protect iron by electro or chemical deposition of copper and its alloys. When electro-depositing was a new invention, several patents were secured for the same idea in its crudest form—viz., the precipitation of copper on iron from acid solutions. All these have utterly failed; the copper peels off, leaving a surface of iron far more corroded than if no attempt at protection had been made.

Some interesting investigations recently made by Mr. W. H. Johnson, of Manchester, on "The Influence of Acids upon Iron and Steel," afford a clear explanation of this. He finds that acids not merely attack the surface of iron, but rapidly penetrate it, and, like the tin and zinc above referred to, can be detected within the iron when a fracture is made. He finds that acids which have thus penetrated, not only continue their corrosive action, but, aided doubtless by the hydrogen evolved and occluded, they seriously diminish the tenacity of both iron and steel.

All who have practically investigated this subject of coppering and brassing iron agree in concluding that if the liquid in which the copper or alloy is dissolved is of itself capable of acting corrosively on the surface of iron, no reliable adhesion of the precipitated copper or brass is possible. By using neutral or alkaline solutions, such as those in cyanide of potassium, an adherent film may be obtained; but even this is not satisfactory, the copper, especially when moderately thick, being very liable to "buckling." This tendency is, I suspect, in a great measure due to the unequal expansion of copper and iron. When raised from 32 to 212 deg. Fah., copper increases in bulk $\frac{1}{194}$, or in length $\frac{1}{582}$, while iron increases only $\frac{1}{282}$ or $\frac{1}{846}$, or, otherwise stated, the expansion of copper when heated, and its contraction in cooling, is nearly one-and-a-half times greater than that of iron. This is a very serious difference, and its practical operation must be the exertion of a continual tearing strain between the two adherent surfaces. I have tested the adhesion of many specimens of such coppered iron by directing the point of a blowpipe flame against a portion of its surface, or, what amounts to nearly the same, by burnishing a portion of the copper surface. In either case an excessive expansion of the copper was produced, and a blister of the copper film was the result. These, of course, are very severe tests, especially the burnishing, which leaves a permanent blister.

Another defect arises from the porosity of such deposits. Although the pores may be invisible to the naked eye, they nevertheless usually exist, and are of sufficient magnitude to admit atmospheric agents, which act upon the iron surface with an energy which is intensified by the voltaic induction due to the electro-negative copper.

These defects have been to some extent remedied by first tinning or zincking the iron and then depositing the copper on the alloyed surface, but the additional expense of this process limits very seriously its applicability, and leaves large structural iron altogether out in the cold.

I must not conclude without some discussion of the merits of enamelling, even though its applicability is as obviously limited. If mere unchecked theorizing were permissible on such subjects, it might be assumed that this a really perfect protective process, the enamel itself being practically imperishable, in reference to corrosive atmospheric agency, and the iron basis affording to the porcelain surface just that tenacious core which its own brittleness demands. But here again inequality of expansion and porosity seriously limit the value of this theoretically beautiful process. The co-efficient of expansion of the vitreous compounds used for enamelling is about $\frac{1}{1000}$, against the $\frac{1}{846}$ of iron, and the brittleness of the enamel renders fatal even a very small difference of expansion or contraction. This is shown in the ruin that comes upon those apparently perfect and beautiful devices, the enamelled frying-pans, saucepans, etc. They chip and scale most vexatiously.

While I was engaged as the teacher of chemistry and its practical applications in

the Birmingham and Midland Institute, an eminent Birmingham firm in the hollow-ware trade consulted me in reference to an improved process of enamelling that was offered for their adoption. The inventor was hardy enough to suppose that it might be applied to the manufacture of evaporating basins and other vessels, in which acids, etc., were to be heated. I devised a simple test which proved quite effectual, and which I venture to recommend for general use in such cases. Some evaporating dishes were made, and I immersed these in a strong solution of sulphate of copper, leaving them there about twenty-four hours. The result was very disagreeable; a large number of small copper warts were dotted on the surface of the enamel, and were especially abundant on the edges of the dishes at the junction between the blue outside and white inside coating of enamel. Mere immersion in acid showed nothing unless continued for several days; but the deposition of copper in the minutest pores, and its outward cauliflower-like expansion, displayed at once those defects, which would have become more vexatiously and mischievously apparent in the course of time had large vessels been made and practically used.

If any enamel stands this test, I think it might be safely warranted for ornamental and other purposes, where the enamelled articles are not exposed to great fluctuations of temperature, such as sign-plates, etc. I have not thus tested any of those which have been lately introduced.

A perfect, or at least satisfactory, and generally applicable method of preserving iron, has yet to be invented. I do not think that the problem is by any means insuperable, for the principle upon which its solution must be based can be clearly stated, and this is an important step towards effecting it. We require something which may be applied easily over large or small surfaces like a paint varnish or lacquer; but it must not be a paint, nor a varnish, nor a lacquer; it must be no mere heterogeneous film holding on by mere mechanical surface adhesion; it must be chemically attached to the iron, as their sulphide and sulphate films are attached to bronze and lead.

What I have already explained respecting the protective action of the compounds of iron with phosphorus, and with silicon or silica, affords fair indication of the direction of research. The ordinary enamels are vitreous compounds of foreign metals fused over the surface of the iron; what we require is to glaze the iron by vitrifying *its own surface*. The Protean solubilities of silicic and phosphoric acids obviously suggest the possibility of doing this without having recourse to fusion at high temperatures. Such a film of iron-glass upon iron would not deface or materially alter the natural appearance or tone of the metal. It would satisfy æsthetic as well as chemical requirements.

The unquestionable importance of fulfilling these desiderata, and a belief in the possibility of doing so, are my main reasons for having thus examined in detail the merits and demerits of the ordinary expedients for protecting iron surfaces, and the elements of the problem which still remain unsolved.

THE FACTOR OF SAFETY IN ENGINEERING STRUCTURES.

By RICHARD H. BUEL.

From "The Iron Age."

Comparatively few engineers have the time or means to conduct thorough experiments on the strength of the materials which they are called upon to use, and in designing work they are generally obliged to accept the results of previous experiments. Fortunately, however, the ultimate strength of most of the materials in common use has been quite accurately determined, for the various strains to which they are subjected —and the engineer has only to decide how much of this ultimate strength he will use for a working load, or what factor of safety he will employ, the factor of safety being the quotient arising from dividing the ultimate strength by the working load.

In choosing this factor, there are several things to be considered—not only the kind of strains, whether tensile, compressive, transverse, torsional, or shearing, that will act upon the material, but also how these strains are to be applied, whether gradually, or all at once, after the manner of a blow. Other matters affecting the choice of a

factor of safety will be mentioned further on. It is easy to see that the effect of a quiescent load upon a structure will be quite different from that of the same load suddenly applied. Suppose, for instance, that a force P is gradually applied to a bar, increasing its length by an amount S. The force commences to act with an intensity of nothing, increasing by slight degrees to P, so that the mean pressure exerted during the elongation is $P \div 2$, and the work of stretching the bar, called the work of resilience, may be represented by the expression $(P \times S) \div 2$. If this same force P is suddenly applied, it will act during the elongation with a mean pressure P, twice as great as the former mean pressure—and if, in the first case, the bar is stretched up to its elastic limit, under the latter conditions a permanent set will be produced, or the bar will be broken. This is an experiment that can be performed by any one, using a spiral spring, and applying a weight to it in the two ways previously mentioned. It would appear from this, that in the case of structures which are to be subjected to the action of impulsive forces, not more than one-half of the ultimate strength can be used for a working load. It seems probable that forces do not generally act in this manner in ordinary structures. In the case of railway bridges and tracks, which are required to sustain a rolling load, both theory and experiment show that the force is more injurious to the material than if it were gradually applied, and that the effect is somewhere between that produced by quiescent and sudden loads, depending upon the speed of the moving train.

Mention has been made of the elastic limit, or the point at which a permanent set occurs, after the material is elongated, compressed, bent or twisted, and it was formerly supposed that when a set was produced, the value of the material for resisting strains was destroyed. Subsequent experiments have shown, however, that a material may take a set without having its strength impaired, and the limiting strain is that which does not increase the set, if repeatedly applied. The weight that will produce this limiting strain is called the proof strength of the material; and as this must never be exceeded in practice, it is evident that the engineer is interested in knowing the proof rather than the ultimate strength of the materials which he is to use. Experiments in regard to the ultimate strength of materials have been more extended than those relating to the proof loads, and hence the constants for the latter cannot be given with so much precision as for the breaking weight. From such experiments as have been made, however, many valuable conclusions have been derived, and it may be well to devote some little space to their consideration.

In regard to tensile strength, the following table gives average values in a few cases:

Tensile strength in pounds per square inch of cross section. (*Strain applied gradually.*)

Material.	Ultimate Strength.	Proof Strength.
Cast Iron	16,500	8,250
Wrought Iron (bar)	45,000	22,500
Wrought Iron (boiler plate)	50,000	25,000
Pittsburgh Steel (plate)	95,000	42,500
Bessemer Steel	99,000	44 500
Black Diamond Steel (bar)	120,700	60,350

These materials, when subjected to the action of sudden strains, give varying results—some of the strongest materials being broken by a blow which does not injure the weaker ones. This is because the elasticity of a material frequently varies inversely as its strength, so that the stronger grades are not so well able to resist shocks as inferior varieties. The following table, token from Trautwine's "Engineer's Pocket Book," to which valuable work the writer is indebted for many of the figures used in this article, will illustrate this fact:

Ultimate tensile strength in pounds per square inch and elongation in inches, before breaking.

(Note.—The specimens tested were steel bars of different grades, made from pure Swedish iron, and each bar was turned down to a diameter of 1 in., for a length of 14 in.)

Specimen.	Per cent. of Carbon.	Breaking Weight.	Elongation in inches.
No. 1	.33	68,100	1.37
No. 2	.43	76,160	1.37
No. 3	.48	84,000	1.25
No. 4	.53	95,200	1.12
No 5	.58	92,960	0.81
No. 6	.63	100,800	1.00
No. 7	.74	101,920	0.69
No. 8	.84	123,200	1.12
No. 9	1.00	134,400	1.00
No. 10	1.25	154,560	0.62

It appears from the foregoing remarks that the proof strength of metals used for structures, in reference to tensile strains gradually applied, has an average value equal to one-half the breaking weight, this value varying with the quality of the material. As many structures are exposed to strains acting somewhat in the nature of blows, not more than half the proof strength should be used as a working load. This fact is recognized by reputable engineers,

who, in designing iron bridges, proportion the parts composed of wrought iron to bear a maximum tensile strain of from 10,000 to 12,000 lbs. per sq. in., and many consider that 8,000 lbs. per sq. in. should be the extreme limit for the working load, on account of some other facts in regard to the strength of materials, which will be briefly considered.

The constants used by the engineer in his calculations are generally obtained by experiments upon small pieces of the materials. Now, it is well known that increase of strength does not always follow in direct proportion to increase of size. A large wooden beam, for instance, is more liable than a small one to be weakened by knots and other imperfections, and on account of the difficulty of securing equal cooling in making large castings, large cast-iron beams are frequently weaker in proportion to their size than small ones. It may be mentioned, in this connection, that Mr. Hodkinson found it necessary to make corrections in his rules for the strength of cast iron pillars, after experimenting upon pillars of larger size.

Structures exposed to the weather are subjected to great variations of temperature, and when metals are cooled, although they resist quiescent loads quite as well as before, they are more easily injured by sudden shocks, such as are caused by rolling loads.

It is commonly recommended in treatises on the strength of materials, that from $\frac{1}{4}$ to $\frac{1}{8}$ of the ultimate strength of the materials should be taken for a working load; but it would seem that the proof strength is really the limit to be considered. This can be illustrated again by a reference to the resistance of materials to transverse strain. The application of a load to a beam causes a deflection, and, if the proof load is exceeded, the material can no longer be regarded as safe. From the results of experiments on the deflection of beams, the following table is compiled.

Average values of ultimate and proof strength in pounds, of beams one inch square and one foot in length between supports, when supported at both ends and loaded in the middle, the load being gradually applied.

Material.	Ultimate Strength.	Proof Load.
Cast Iron	2,000	800
Wrought Iron	2,400	1,000
Steel	6,000	5,000
White Pine	450	150
Oak	600	200

These, it must be remembered, are average values, the same variations being observed in different qualities of the same material when suddenly strained, as previously remarked in the case of tensile strength, so that really the proof strength is the only safe figure from which the engineer can deduce the factor of safety. Average values of these factors, so that the load shall equal the proof strength, are given below:

	FACTOR OF SAFETY.	
Material.	Load gradually applied.	Impulsive Load.
Cast Iron	2.5	5.
Wrought Iron	2.4	4.8
Steel	1.2	2.4
White Pine	3.	6.
Oak	3.	6.

It will be seen that the proof loads vary with the different materials, whence the factors of safety for the working loads will also vary, if they are taken with reference to the ultimate strength of the materials, while, if calculated with respect to the proof loads, they will be the same in every case. This will be rendered clear by the accompanying table, which also contains other matters of interest. (See Table A.)

The breaking weight W, W′, W″, in the above table, are to be calculated for any particular case by the formulas in general use, using for constants the figures given in tables of the transverse strength of materials. The deflections, D, D′, D″, can be calculated or determined experimentally for a beam supported at both ends and loaded in the middle, when the deflections for other distribution of the load are given at once from the table. The deflections d, d', d'', are determined in the same way for any loads less than the proof, and the table shows the corresponding deflections when this same load is differently applied. By observing the relations given in the table, the load required to produce any deflections within that produced by the proof load, can readily be calculated. The safe load assumed in the table is one that is approved by experiment, though somewhat smaller than is often allowed. The following table is calculated for this load, or with a factor of safety of one-third the proof strength. (See Table B.)

Before concluding, a few remarks will be made about the factor of safety for the iron used in the construction of steam boilers. The most reliable authorities on this subject state that a factor of 6 in relation to ultimate strength is the least allowable,

TABLE A.

Rectangular Beams, loaded so that the deflection shall not exceed one-third of that caused by the proof load.

Material.	Distribution of Load.	Breaking Weight.	Proof Load.	Deflection under Proof Load.	Deflection under the same Load.	Assumed Safe Deflection.	Load that will produce Safe Deflection.	Factor of Safety.	
								In reference to ultimate Strength.	In reference to proof Strength.
Wrought Iron.	Supported at both ends, and loaded in the middle	W	0.417 W	D	d	0.333 D	0.138 W	7 2	3
	Supported at both ends, and uniformly loaded	2 W	0.833 W	1.25 D	0.625 d	0.417 D	0.278 W		
	Fixed at one end, and uniformly loaded	0.5 W	0.208 W	3 D	6 d	D	0.069 W		
	Fixed at one end, and loaded at the other	0.25 W	0.104 W	4 D	16 d	1.333 D	0.034 W		
Cast Iron.	Supported at both ends, and loaded in the middle	W′	0.4 W′	D′	d′	0.333 D′	0.133 W′	7.5	3
	Supported at both ends, and uniformly loaded	2 W′	0.8 W′	1.25 D′	0.625 d′	0.417 D′	0.267 W′		
	Fixed at one end, and uniformly loaded	0.5 W′	0.2 W′	3 D′	6 d′	D′	0.067 W′		
	Fixed at one end, and loaded at the other	0.25 W′	0.1 W′	4 D′	16 d′	1.333 D′	0.033 W′		
Timber..	Supported at both ends, and loaded in the middle	W″	0.333 W″	D″	d″	0.333 D″	0.111 W″	9	3
	Supported at both ends, and uniformly loaded	2 W″	0.667 W″	1.25 D″	0.625 d″	0.417 D″	0.222 W″		
	Fixed at one end, and uniformly loaded	0.5 W″	0.167 W′	3 D″	6 d″	D″	0.056 W″		
	Fixed at one end, and loaded at the other	0.25 W″	0.083 W″	4 D″	16 d″	1.333 D″	0.028 W″		

TABLE B.

Safe Loads, in Pounds, for Rectangular Beams whose length between supports is l feet; breadth, b inches; depth, d inches; and unsupported weight of the beam, B *pounds.*

Distribution of Load.	Wrought Iron.	Cast Iron.	White Pine.	Oak.
Suported at both ends, and loaded in the middle...	$333 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$267 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$50 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$67 \times \frac{b \times d^2}{l} - \frac{B}{2}$
Supported at both ends, and uniformly loaded...	$667 \times \frac{b \times d^2}{l} - B$	$533 \times \frac{b \times d^2}{l} - B$	$100 \times \frac{b \times d^2}{l} - B$	$133 \times \frac{b \times d^2}{l} - B$
Fixed at one end, and uniformly loaded.....	$167 \times \frac{b \times d^2}{l} - B$	$133 \times \frac{b \times d^2}{l} - B$	$25 \times \frac{b \times d^2}{l} - B$	$33 \times \frac{b \times d^2}{l} - B$
Fixed at one end, and loaded at the other.....	$83 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$67 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$13 \times \frac{b \times d^2}{l} - \frac{B}{2}$	$17 \times \frac{b \times d^2}{l} - \frac{B}{2}$

while it is more desirable to use a factor of 8. The experiments of Sir William Fairbairn have shown that the strength of a single riveted joint has but 56 per cent. of the strength of the sheet, and that a double riveted joint, properly constructed, has 70 per cent. The average tensile strength of boiler plate, as given above, is 50,000 lbs. per sq. in., and much is used that falls below this figure. This will give the ultimate strength of the riveted joint as follows:

Double riveted	35,000
Single "	28,000

Hence the greatest allowable working load should be:

Double riveted	5,833
Single "	4,667

And the best authorities recommend that the working load should not exceed:

In boilers with double riveted joints	4,375
" " " single	3,500

A committee appointed by the Franklin Institute, of Philadelphia, to determine a safe value for the strain upon steam boilers, have recently reported to that body. They assume the ultimate tensile strength of a single riveted joint to be 34,000 lbs. per sq. in., and recommend that 6,000 lbs. per sq. in. be taken for the working strain. If the foregoing data are correct, this allows a factor of safety of $28{,}000 \div 6{,}000 = 4.67$, far below what is generally assumed to be a safe limit. It may well be doubted whether this influential body has not committed a grave error in pronouncing this opinion.

THE MANUFACTURE OF FIRE-CLAY GOODS.

From "The Builder."

Manufactures in fire-clay, comprising, as they do, many articles other than those which must necessarily possess fire-resisting properties, are rising in importance to an extent not generally recognized; some idea of which may be formed from the fact of fire-clay goods being used for the lining of furnaces and domestic fireplaces, the drainage of towns, and the ornamentation of public buildings.

Fire-clay is found in various parts of Great Britain; the most noted seams occurring at Dinas, in Wales; Kilmarnock and Glenboig, in Scotland; and Stourbridge, Plympton, Newcastle, Burton-on-Trent, Poole, Hedgerley, and Wortley, in England. The celebrated Dinas rock, when made into bricks, is almost pure silica; but generally the proportions are 59 to 84 per cent. of silica, 36 to 8 per cent. of alumina, with small quantities of peroxide of iron, lime, magnesia, potash, and soda. Generally speaking, the more the first and less the five last-named substances preponderate, the greater will be the value of the clay they compose.

The occurrence of fire-clay, and the strata with which it is associated, vary in almost every case; it is usually found in the coal-measures, immediately underneath the coal; and, as space precludes, and similar conditions render unnecessary a description of its position and mode of working in every locality, a brief account of what is done in the Wortley district (near Leeds) will be given as sufficient for the purposes of this article.

In a district, remarkable from a geological point of view; broken up by faults in the strata into areas; separated, as far as the mining engineer is concerned, although continuous to the farmer; averaging rarely as much as 100 acres each, occurs a seam of coal from 8 in. to 18 in. thick, and from 10 yards to 120 yards below the surface, known as the "Better Bed," and remarkable for its freedom from sulphur, and consequent value for iron smelting. Underneath this bed of coal occurs a silicious rock of bluish-grey color, containing impressions of plants, sigillaria, etc. When the depth is not more than about 80 yards below the surface, it is of a shaly nature, and falls to pieces after being exposed to the atmosphere, and is the fire-clay proper; but, as the depth increases, this rock becomes more of a stony nature, and unfit for manufacturing purposes. [The word "rock" is used in its geological sense, meaning any layer of material, soft or stony.] The thickness of the fire-clay is about 2 ft., and it is obtained along with, and in a similar manner to, the coal.

The clay being raised to the surface and conveyed to the works, the process of manufacture commences by (1) grinding, separating, and mixing; (2) moulding and drying; and (3) burning and (when re-

quired) glazing. The clay being "weathered," or disintegrated by atmospheric action, it is thrown into a flat-bottomed circular revolving pan, about 9 ft. diameter, having two stationary rollers about 5 ft. diameter, 15 in. wide, and each 2½ or 3 tons weight; by these the clay is crushed to a powder sufficiently fine to pass through gratings, ½ in. wide, in the pan bottom. After leaving the pan, the clay—now in a state of somewhat dry powder—is raised by an elevator, consisting of sheet-iron cans attached to an endless band, to the top of a series of screens, varying in degree of fineness, by which the clay is separated accordingly; and any coarse lumps that will not pass the screens are returned to the grinding-pan.

The men who work near the screens have to breathe an atmosphere in which fine dust floats to an unpleasant extent. A plan is about to be tried at one of the principal works in the Leeds district to separate the clay by a fan in a long chamber, the air being filtered by having to escape through sheets of canvas at the end opposite to which the fan is placed; if this succeeds, the finest dust, which is the most valuable, will be available for the best class of ornamental tiles, etc., and the grinding-house a more tolerable workshop than it is at present.

The clay is usually separated into four degrees of fineness, according to the work it is required for; and this being done, it is thrown or mechanically conveyed into a pan similar to that described for grinding, but with a solid bottom, and rollers about half the weight; with the addition of a certain quantity of water, it is mixed into a paste in a short time, and so thoroughly that a pastry cook could not find fault with, but might wish for a similar apparatus to reduce the labor now necessary to provide for the demands of our juveniles for tarts. A scoop, which the attendant soon learns to handle dexterously, empties the mixing-pan while revolving, and deposits the pasty clay into a barrow, or small four-wheeled wagon, in which it is conveyed to another department for further operations.

When the clay has to be used in large masses, such as retorts for gas works, large drain pipes, etc., powdered fire-bricks or fire-clay goods that may have cracked while burning, are added to the clay when being mixed; and for the crucibles used by brass founders and others, plumbago or carbon in some other form is added. Various mixtures are employed; for instance, the best terra-cotta is produced by certain proportions of fire-clay mixed with Dorsetshire plastic clay.

As the treatment of the clay differs for the various articles made, it will be necessary to describe the moulding and burning for each kind. Premising that the clay is delivered to the workmen in a plastic condition, the manufactures may be said to consist of common fire-bricks, retorts for gas works, sanitary tubes, glazed and enamelled bricks and terra-cotta.

Fire-bricks are made in a large shed, in which tables are placed; at each table a man is stationed and kept supplied with clay. The moulds consist of what may be called a rectangular box, without top or bottom; the clay is first kneaded by the brickmaker to a shape roughly approximating to, and then pressed into the mould. [Here an intending visitor to the brickworks may be cautioned against going too near the table (if his coat is a good one), as brickmakers take a cruel pleasure in bespattering respectable clothing.] Two boys are required to carry away the bricks made by one man; and they are then laid upon the floor, heated by steam, or the products of combustion from fires placed at one end that pass under the floor on their way to the chimney; by these means the bricks are dried so as to bear piling in the kiln. As an illustration of the necessity of employing a material that is a good conductor of heat to form the floors of drying-sheds, it may be mentioned that a floor made of cast-iron plates will cost nearly three times as much as a fire-brick floor; but will only require about two-fifths of the fuel to dry the same quantity of bricks; the saving in coal being 56 per cent. in favor of the iron floor.* The bricks are now ready for burning. The kilns considered best are rectangular, about 40 ft. long, 20 ft. wide (outside), and 8 ft. or 10 ft. high inside; the top is arched over, and in this arch are small openings at intervals for the whole length, to allow steam and products of combustion, after having circulated among the bricks, to escape. The fireplaces are on both sides of the kilns; and according to the number on one side, they are designated "8-holed" or "10-holed" kilns.

Retorts are round, oval, and D shaped

* From experiments by the writer.

about 3 in. thick, 4 ft. to 10 ft. long, and are built up in annular wood moulds. The clay, being used in large masses, must possess a certain degree of porosity to insure thorough burning and non-liability to crack; this is secured by adding to the fire-clay when in the mixing pan, fire-clay material that has been previously burnt, and afterwards powdered, as before mentioned (and sometimes sawdust also); so that when the built-up retort is being burnt, the raw clay shrinks, while the "rough stuff" retains its original bulk (sawdust, when used, being consumed), and the finished article left sufficiently porous. The shrinkage of fire-clay is such that any article to be 12 in. long after, must be 13 in. before, being burnt.

Sanitary tubes are made in a machine; the best consisting of a cylinder having an open top, and an annular opening in the loose plate that covers the bottom equal to the transverse section of the pipe it is required to produce. In the cylinder fits a piston, attached to the end of the rod of another piston working in a steam cylinder placed immediately above that for the clay. When a pipe is to be made, the pistons are raised by admitting steam into the lower end of the upper cylinder; the lower piston being then raised some inches above the top of the clay cylinder, so as to allow plastic clay to be thrown in. By admitting steam on the top side of the upper piston, the clay is forced by the lower piston through the annular opening in a manner analogous to the working of a sausage machine, only that a hollow instead of a solid stream issues from the pipe press. The pipes are cut off by a wire to the required length (generally 2½ ft.), and the sockets for small pipes (3 in. to 8 in. diameter) are luted on by hand, although there are machines with a pair of movable dies to form the body of the pipe and its socket at one operation, similar to the larger machines; but little more than half the quantity can be made by the same machine when the sockets are also formed by it. The tubes are set vertically, and dried by heat from steam pipes placed about 6 ft. *above* the floor on which the tubes stand, so as to dry the sockets first; after which they are turned over for the "spigot" (or plain end that fits into the socket of the pipe next to it when laid), to be "fettled." By these machines, tubes can be made with rapidity up to 30 in. diameter, in quantities varying according to size, from 3,000 to 150 per day per machine. Sanitary tubes (and retorts) are set in kilns with their axes vertical, so that the flame can pass both outside and through them. To give the tubes the glaze, which all who have seen a town drain being put in have doubtless noticed, chloride of sodium (common salt) is thrown into the fire; the heat being sufficient to volatilize it, and cause a coating of silicate of soda to be formed on the exposed surfaces of the tubes.

The application of bricks having glazed enamelled faces to the interior of bath-rooms and baths, fishmongers' and other shop walls, the walls of entrances and passages of private houses, lavatories, etc., is another advantage for which those who design buildings, and those who keep them clean, are indebted to the manufacturer. For durability, cleanliness and cheapness combined, these bricks are unrivalled. They are produced in various colors; Venetian and coral reds, black, greens and blues of various shades, grey, drab, buff and white; the tints being stated in the order that they are charged for; red being the most difficult, and white the easiest to obtain perfect.

After being moulded and dried, similar to fire-bricks, they are taken to a powerful screw press, from which they issue perfectly square and smooth on the angles and surfaces. The coloring matter is applied by dipping the bricks into "slip," a felspathic and silicious liquid of the consistency of good cream; they are then laid on shelves in the drying shed until the following day, when the glaze is applied on a similar manner to the "slip." The bricks ordinarily made are "headers," which are glazed in one end only; "stretchers" on one side; "splayed ends," having a triangular piece cut off one corner, and glazed on the three sides formed by what were two in the common brick; and "bull noses," having one corner cut off by a quarter of a circle, and glazed round it and the adjacent side and end. For all colors, excepting white, the bricks have to be burnt after "slipping," and again after glazing; no kind of colored "slip" having yet been discovered that will bear the application of glaze before a preliminary burning. For this class of work the greatest care is necessary in every stage of the process, to avoid chipping the corners or defacing the exposed surfaces before and after burning, to maintain the proper heat in the kilns, and

to see that a first-rate quality of coal is used. Chimney-pots, and terra-cotta wares generally, are made in plaster moulds, the manufacture being more or less complicated, according to the degree of ornamentation; they, and the enamel-colored glazed bricks, have to be burnt in "muffled" kilns —or those in which the flame does not come in contact with the articles being burnt. The good quality of these wares is indicated by a pure and regular color, smooth faces, sharp edges, and a clear ringing sound when struck.

This description of the fire-clay manufacture is necessarily a very general, and, to some extent, an incomplete one. Many modifications are thought to be advisable by some manufacturers, both in machinery and methods of working; but as a brief account of the practice of some of the most eminent firms in the trade, it may be accepted as showing the degree of perfection at present reached; future inventors will, doubtless, increase the facilities for producing articles, the demands for which are now in excess of the supply.

STEAM REGENERATION.

From "The Engineer."

A short time ago, a party of scientific men assembled at Stafford House, by the invitation of the Duke of Sutherland, and became witnesses to one of those pretty little puzzles in natural science which serve to show that our definitions are occasionally somewhat too narrow to comprehend all the facts to which they stand related. To make a body hotter by bringing it in contact with a colder one seems altogether a paradox, unless we include the idea of chemical action. So also, to think of condensing steam by passing it into a liquid hotter than itself seems rather a forlorn hope. When Mr. Spence proposed to apply steam in such a way as to make a liquid boil at a temperature much higher than that of the steam itself, he was told that such a result would be "contrary to the laws of nature." Nevertheless, Mr. Spence was prepared to perform the feat, seeing that he had already accomplished it. So at Stafford House he —or rather his son—boiled water in a flask, and turned the steam into an open glass tumbler containing a certain liquid with a boiling point considerably above that of water. After a few minutes this liquid apparently boiled, and gave off steam which was estimated as equal to a pressure of 30 lbs. on the sq. in. The liquid was simply water with a strong admixture of caustic soda. We have since repeated the experiment, taking care to have the caustic soda thoroughly dissolved before introducing the steam. By this precaution we excluded the effect of the heat which is evolved while the alkali is dissolving. The steam from the flask of boiling water was then introduced, and in a few minutes the temperature of our solution rose to 226 deg. Fahrenheit, where it remained stationary. In this instance the solution was placed in an open-mouthed flask, and the temperature of the rising steam in the neck of the flask was between 215 and 216 deg. There was a good deal of agitation in the liquid, but we can hardly say it was boiling.

During the exhibition of the experiment at Stafford House, the elder Mr. Spence offered an explanation of the phenomenon in the language of the old material theory. He suggested that the caustic alkali had a greater affinity for water than for caloric. Hence the soda arrested the water of the steam, and liberated the accompanying caloric, which accordingly became free to heighten the temperature of the surrounding liquid. Of course, this antiquated philosophy jarred somewhat on the ears of the *savants*, and Colonel Strange intimated that if Mr. Spence was going to work on that line, he would have to fight a battle with all the physicists in Europe. Still, although it was easy to quarrel with the calorific hypothesis, nobody suggested anything better. There was the thermometer, very provokingly sticking fast at some elevated temperature far above the boiling point of water, and nobody seemed any the wiser for it. *Cui bono?* was one question, and in answer to this, Mr. Spence exhibited a diagram showing a method for turning waste steam to profitable account. For some time the audience could not quite understand the diagram, and when they did they refused to believe in it. Mr. Crampton was zealous in his questioning

and kindly in his suggestions, but held out very little hope that this caustic soda business would lead to any profitable issue. Another authority considered that nothing could excel the simple method of turning the waste steam into the tank from whence the boilers took their supply. The grand problem was to know what Mr. Spence could do with a pound of coal. If he could economically get coal to raise more steam than heretofore, fame and fortune were his.

A cheque, somewhere between £100 and £1,000, would suffice to show what was the state of the case in this respect, and for this further adventure the audience were willing to wait, evidently expecting very little to come of it. Something is due to the acuteness of the elder Mr. Spence in detecting a phenomenon hitherto so little known as to be disbelieved when stated. The younger Mr. Spence has embraced the idea that the peculiar property thus observed may be turned to a practical use, and there is a possibility that he may not prove altogether wrong. The phenomenon has not been entirely unknown in the past, although almost universally overlooked. We have reason to know that Mr. Perkins —celebrated as the apostle of high pressures—many years back made experiments resembling the one to which we have just referred, though with a different material. As the matter has thus been rendered prominent of late, and no satisfactory explanation has been forthcoming, we have thought it worth while to attempt a further investigation of the phenomenon. For this purpose a solution of caustic soda was made, containing 36 per cent. of alkali. The boiling point of this solution was found to be 239 deg. Fahr. A quantity of this solution, equal to 4,420 measured grains, was placed in a glass flask to which were fitted two thermometers, one to indicate the temperature of the alkaline solution, and the other that of the exit steam ; a tube for conducting steam from a flask of boiling water dipped into the alkaline solution being immersed to the depth of about 3½ in. The water in this other flask amounted at the outset to 3,500 measured grains. In adjusting the thermometer which was to show the temperature of the exit steam, care was exercised that neither radiation of heat from the alkaline solution nor any splashings from the boiling liquid could reach it so as to affect the readings.

Flame being applied to the flask of water, the temperature rose until the liquid boiled. A lesser degree of heat was applied to the flask containing the solution, so that the temperature of the latter immediately before the steam entered it was 133 deg. With the entrance of the steam the temperature rapidly rose until it reached 233 deg. A higher temperature would doubtless have been obtained had not the condensation of the steam diluted the liquid, and thereby lowered its boiling point. As a matter of fact, the observed temperature of 233 deg. may be taken as the boiling point of the solution as it then existed. The exit steam never rose above 209 deg., which is not a little curious. The experiment lasted about forty minutes, and during the latter part of the time the temperature of the solution sank from 233 deg. to 229 deg., a result doubtless occasioned by the lowering of the boiling point in consequence of the dilution of the liquid by the continued condensation of the steam. After the above lapse of time the boiling was discontinued and the apparatus disconnected. The water remaining in the flask was then found to be 1,750 grains, while the volume of the soda solution had become augmented to 5,750 grains. The quantity of water converted into steam was, therefore, $3500 - 1750 = 1750$ grains, or exactly half. Referring to the alkaline solution, we observe that starting with 4,420 grains, the amount at the end of the experiment was 5,750 grains, showing, therefore, an augmentation of 1,330 grains. Deducting this increment from the total quantity of water evaporated, we get 420 grains. Accordingly we are led to the conclusion that out of 1,750 grains of water converted into steam, no less than 1,330 were imparted to the alkaline solution, while only 420 grains passed off finally as free steam.

The latent heat of steam at the ordinary pressure of the atmosphere is 934; that is to say, every pound of steam condensed to water evolves sufficient heat to raise 934 lbs. of water 1 deg. Fahr. The alkaline solution was raised from 133 to 233, or 100 deg., and was maintained nearly at that temperature throughout the period of forty minutes. As one grain of steam can raise 934 grains of water through 1 deg., so 1,330 grains of steam—the weight condensed in the alkaline solution—are capable of raising 1,242,220 grains of water 1 deg., or 12,422 grains of water 100 deg. As, however, the

specific heat of a solution of potash is less than that of water, the steam in this case will actually do more. Taking the specific heat of water as unity, that of our solution would be 0.931. Hence the steam would raise about 13,000 grains through a range of 100 deg. As the actual quantity of the solution was only 4,420 grains, we see that theoretically the latent heat from the steam would really raise nearly three times the amount of soda solution through the observed range of temperature. The excess of heat shown by theory was in all probability lost by radiation, as during the forty minutes occupied by the experiment no provision was made to prevent the radiation of heat, the flask of alkaline solution being wholly unprotected.

Of course we do not pretend that the foregoing calculation is to be taken as altogether exact. Certain corrections are obviously required; but scrupulous exactness is unnecessary, as we are only seeking for a principle, which is abundantly demonstrated by those results which the most refined analysis would leave untouched. Proceeding with our experimental investigation, the next step consisted in trying the effect of steam on water in which a neutral salt had been dissolved. Thus a saturated solution of common salt was prepared, and the boiling point was found to be 228 deg. Steam passed into this solution raised the temperature as high as 226.5 deg. Finally, an acid was employed, a solution being prepared by mixing one part by measure of sulphuric acid, specific gravity 1.84, with three parts of water. The boiling point of this mixture was 237 deg., and the admission of steam into it raised the temperature to 229 deg. It is singular that in this last experiment the original boiling point of the solution was not more closely approached, the deficiency being decidedly greater than when the other solutions were employed. Taking the three substances used in solution, namely, caustic soda, chloride of sodium, and sulphuric acid, as representatives of alkalies, salts, and acids respectively, and seeing that in each case the same phenomenon occurred, it is a fair inference that any form of matter which would raise the boiling point would give a like result. The idea of an explanation being offered by the fact of caustic soda having an affinity for water, is evidently displaced by these more general results. That steam passing into a solution with a high boiling point is capable of producing a temperature higher than that of the liquid from whence the steam proceeds, is perfectly clear; and this result is evidently due to the latent heat of the steam, which again leads us to the conclusion that, during the latter part of the process, the steam undergoes condensation in a liquid hotter than itself. The solution seems to have the property of absorbing heat until its own boiling point is attained, and thus reaches a temperature higher than that of the steam by which it is heated, a phenomenon which still remains sufficiently paradoxical. Concerning the steam, we observe that it becomes resolved or condensed into the general volume of the solution, and in that state—while literally condensed—is hotter than it was before.

With regard to the utilization of the property to which we have thus referred, the cost of the material seems to be a serious drawback if caustic soda be employed. Common salt, although giving a lower boiling point, might yield a better commercial result. But are there not waste liquids having a boiling point above that of water? The waste steam of a manufactory might be turned into the waste liquid, and the heat intensified so as to become useful.

DECAY AND PRESERVATION OF TELEGRAPH POLES.*

From "Iron."

The earlier telegraphs were all constructed with the very best Baltic timber. The first line erected for commercial purposes, viz., that between Nine Elms and Gosport, upon the London and South Western Railway, in 1844, was built entirely of the best foreign timber. Of Memel we have considerable experience. For over 100 years it has been largely imported into England, and as largely used where strength and durability have been a matter of importance. Memel, Riga, Dantzic, Norway, Swedish, and what is in England known as

* A paper read before the Society of Telegraph Engineers by Mr. Wm. Langdon.

Scotch fir, are all the same species—*pinus sylvestris*. The great difference which exists in the foreign and home-grown wood is simply the result of the difference of climate and soil. The genus is the same.

It was about the year 1851 that native-grown larch (*larix communis*) was first introduced for telegraph poles. This timber, when used for telegraph purposes, is required to possess the natural butt, as much for durability as for strength. Formerly, round poles were usually specified to be not less than 4 in. diameter at the top, and for heavy lines 5 in. Of later years these dimensions have been increased to 5 in. and 6 in. respectively.

When the tree is cut down, all the undigested liquids in course of time evaporate and disperse, provided it is so placed as to enable this so-called "seasoning" to go on; but if they are allowed to remain they putrefy or ferment. There are two kinds of decay, viz., *dry* and *wet rot*. The former is a slow mouldering action, due to the presence of a species of fungus called the *merulius lachrymans*. To this form of decay we are fortunately seldom subject, but in *wet-rot* we find our great enemy. *Wet-rot* is of two kinds, oxidation and disintegration. The first is a species of slow combustion, or "eremacausis;" the latter explains itself. Experience gives the average life of an unprepared telegraph pole as seven years. In many instances, however, this is considerably over the mark.

The mileage of telegraph lines in England, Scotland, Ireland and Wales, may, at the present time, be fairly stated to be not less than 24,000. Take it that one-half of these lines are built of timber protected by some preservative process—there remains 12,000 unprotected. The renewal of these lines at £20 to the mile—a sum no doubt considerably under the actual cost—represents a sum of £240,000. If we can add to the duration of the life of the timber one-half of the average term (say seven years) it means a saving of £120,000 during every such period.

It is well known that the point at which our poles decay is that at which the greatest strength is required, viz., the ground line known as the *wind and water line*. Wood, when not affected with dry-rot, may be said to retain its lasting properties for a prolonged period, under the following conditions:—1. When kept dry. 2. When continually under water. 3. When wholly buried beneath the soil at such a depth as to secure an equable temperature and moisture. It may safely be said that in no case do telegraph poles conform to any one of these conditions.

I have spoken of the decay due to eremacausis or slow combustion, but there is another process of disintegration of a mechanical nature, and it is this process to which the destruction of our poles is mainly due. In this, the tiny particles of moisture held in the outer pores of the wood first become heated, then volatilize, and finally, bursting asunder the delicate fibres by which they are bound, escape into the surrounding air. No sooner has one particle of moisture burst the bonds of its chamber, than it is followed by another and another, each one aiding in the work of disintegration, until its structure is utterly destroyed.

The methods which are adopted for the preservation of timber from the destructive effects of dry and wet rot are of two kinds —the one applied externally and the other internally. The external applications are:

1. *Seasoning*, the natural system of which is well known; the artificial is by means of hot-air chambers. It is also frequently immersed for a long time in salt water, by which process the sap and germs of decay are supposed to be washed out.

2. *Charring and Tarring.* — Charring consists in slightly roasting or carbonizing the surface of the wood, when it is dry, to a distance of 6 ft. or more from the base of the pole. It expels the sap, if any remain, destroys the external ligneous pores of the wood, coating it with a hard shell, checking absorption, and it kills the germs of animal and vegetable life that exist in that portion of the tree. The portion charred and some 3 ft. of the pole above is usually coated with tar while it is hot. When a pole has been not merely charred, but also well tarred about the wind and water line only, we notice that decay is removed to the point above that so treated, at once giving evidence of the good done, and suggesting that, if the whole of that portion of the pole placed underground had been served in a similar manner, the destructive action might have been still further delayed. The bottom of the pole is frequently neither charred nor tarred. It is here that moisture creeps in, and it is from this point that, under the influence of the higher temperature above, it is drawn upwards, until it reaches that part where the pores of the

wood are no longer sealed up. Here it breaks forth, tearing the fibres asunder, disintegrating and destroying the wood in the manner observed. The tops of the poles, if not preserved from moisture, decay. In some countries they merely point the poles and paint them, but in England they are invariably protected with roofs and caps, usually galvanized iron roofs bent and nailed on the top, sloped for the purpose.

3. *Local Applications.*—The general decay of telegraph poles began to develop itself in the year 1855, and local applications to the "wind and water" mark were applied. Gangs were sent about the country removing the ground to a depth of about 2 ft., cutting off the decayed part of the poles, and plastering it above and below the ground line with asphalt, and eventually with cast iron and earthenware cylinders filled with asphalt. Some years since Mr. Preece attempted to stay its ravages by encasing the butt-end of the pole in an earthenware jar, filling up the space between the jar and the pole by a compound of hot tar, lime, and felt. Mr. Haynes, the telegraph superintendent of the Bristol and Exeter Railway, says that about twenty years since the Electric Telegraph Company erected between Yatton and Worle station three miles of wooden poles, fitted with screw iron sockets. Of these no renewals were necessary until last year. He then found that several of the poles had gone badly near the sockets, and others were rotted near the top. Those that were bad at the bottom were several inches below ground.

The internal application of the best known preservative processes is of two kinds:—1. The introduction into the pores of the wood of some salt, which, uniting chemically with the albumen of the sap, is stated to convert it into an insoluble compound. 2. The introduction of some oil, which not only acts as an antiseptic, but renders the woody tissue water-proof. Under the first head several processes have been tried; but the best known are Burnetising, Kyanising, and Boucherising.

Burnetising consists in impregnating the timber when dry with a solution of sulphate of zinc. The original poles on the London and South Western Railway, erected in 1844, were so served, as were others erected on the Midland in 1846. They were in both cases of the best Memel timber. After sixteen years, Mr. Preece reported on these poles as follows:—Of those in sand, 74 out of 97 required spurring; in chalk, 50 out of 112; in gravel, 25 out of 70; in clay, 18 out of 73. All these poles were renewed by the end of 1871.

Kyanising consists in impregnating the timber with a solution of corrosive sublimate (mercuric chloride). In both Kyanising and Burnetising open tanks are filled with the solution with which the timber is required to be charged. The timber is then submerged in it, well fixed down, and allowed to remain soaking until it has absorbed the proper quantity of the solution. On the Cornwall Railway some 400 larch poles, prepared under this process, were erected some seven years since. Mr. Webber, the telegraph superintendent of that line, states they are apparently as sound as ever.

Boucherising consists of impregnating the timber with sulphate of copper. This is effected by applying a solution of this description to the butt-end of the pole under a gentle pressure provided by the weight of the liquid itself, which is usually arranged in tanks at a height of some 50 ft. above the level at which the timber is placed. The lasting properties which this process imparts to timber appear to vary considerably. Mr. Culley has pronounced the system a failure except under special circumstances. In some instances poles which have not been planted more than six years have been removed owing to dry rot. In other cases they have still been found good after standing thirteen or fourteen years. Boucherising has, in spite of its apparently uncertain action, the recommendation that it can be applied in the wood in which the tree grows, thereby probably saving a considerable outlay in carriage; that poles prepared by it can be made use of immediately; in fact, that a tree may be cut down, hauled into the Boucherising yard, subjected to the process, and erected as a telegraph pole in a month, and this with a prospect of its lasting some ten or twelve years.

Attempts have been made to render timber indestructible by supplying the tree with antiseptic salts while growing. The most complete experiments in this direction were made by Mr. Hyett, who not only supplied the living tree with preservative materials, but changed the color of the wood so as to make beech appear a beautiful mahogany, and larch an exquisite rosewood. In this system, about six inches

from the ground a 2 in. auger-hole is bored quite through the centre of the tree, a narrow saw is then introduced, making a horizontal cut right and left of the tree. A clay basin, holding about two gallons, is arranged around the bottom in which the solution was placed. In this way, it is stated, trees became thoroughly impregnated with the required salt.

We now come to the preservation of timber by oil, and under this head we have simply to deal with that system known as *creosoting*. The theory of the application of creosote is that it is not only an antiseptic, but it destroys any vegetable germ which may exist in the timber, and that it renders it impervious to moisture. Its usual mode of application is by placing the poles within a cylinder, which is then made air-tight, and the air exhausted from it. In exhausting the air it is said any moisture held in the wood is also removed. This is very doubtful. However, the air being exhausted, the creosote is then turned in the cylinder, and injected into the wood, under a pressure varying according to the contents of the cylinder. There can be no question that in creosote we have by far the best preservative yet produced. It is cheap, easily applied, and effective. Perhaps no greater recommendation of its efficiency can be offered than the fact that there is now standing, to all appearance as good as when first erected, a line of poles between Fareham and Portsmouth, on the London and South-Western Railway, which was erected in 1848-9. These poles are now five-and-twenty years old, and, when examined a few months since, gave no sign of decay. In 1861 Mr. Preece, reporting upon this form of preservative, states that out of 318 poles examined only two gave signs of decay, and that at the top of the poles. The poles had been standing twelve years.

In creosote we no longer deal with an *absorbent of moisture*, but with something *directly opposed to it*. Hence its power of resisting that action which has been described as destructive to the pole, and hence the durability of creosote over all other descriptions of prepared timber. Let the timber be dry when the creosote is applied, and let it be applied under proper pressure; the result need not be questioned. But let the timber be wet when subjected to the process, and it is probable that at no distant date the core of the wood, or that portion of it between the heart and the point to which the creosote has penetrated, will become rotten; for to this point will have been driven the moisture contained in the wood. Here it must remain, for there is no escape through the creosote. It must consequently ferment, rot, and destroy the core of the pole.

In employing creosoted timber, care should be taken when the creosoted portion is removed, as is sometimes the case in fixing the tie-pieces at the foot of A poles, that the uncreosoted portion exposed be well tarred, and even where the same occurs above ground—as when slotting poles for arms—that it should in some way be preserved from the effects of wet. No great time since, when railway companies began to make use of creosoted sleepers, it was not an unusual thing to see them fitted for the chairs after they had been submitted to the process. The natural consequence was that the point at which the greatest durability was required was the first to decay. We now see sleepers fitted before being creosoted.

Neither should it be forgotten that, whilst creosoted timber is impervious to wet, it is not so to the sun's rays. A creosoted pole will always show on which side the sun shines. The oil is by his influence brought to the surface of the wood. Some of it evaporates, whilst the rest trickles down the pole, forming a little mass around its base at the ground line. It is desirable for this reason that such poles should occasionally be served with a coat of tar. As to the period at which this should be done, the pole itself will be the best guide. Poles treated under this process differ considerably in the manner and measure in which they accept it. A damp, or a close-grained pole will not receive it so well as a dry or cross-grained pole. As soon as the pole assumes a light rusty brown color, then it is desirable to give it a coat of tar.

In 1870-71 a new line of poles were erected by the Postal Telegraph Department between London and Beachy Head. It was thought desirable that some of the poles used should be creosoted at the base. A large tank was obtained, and arranged so that a fire could be lit underneath it. In the tank was placed a quantity of creosote, which was kept at boiling heat, and the butts of the poles were submerged in it. A man kept in attendance looked to the fire, and kept constantly laving the poles,

so as to secure an application of the process for 6 or 8 ft. of the butt-end of the pole. By this means some twelve or fourteen poles at a time received a very fair surface-coating of creosote, the wood being penetrated from $\frac{1}{4}$ to $\frac{3}{8}$ in.

In conclusion, then, we may gather from the foregoing: 1. That creosoted poles, planted twenty-five or twenty-six years since, are still, apparently, in a state of perfect preservation. 2. That poles fitted with iron sockets which exclude the moisture from the wood, planted twenty years since, are still in a good state of preservation. 3. That specially-selected foreign timber, Burnetised, has lasted with repairs from eighteen to twenty-four years. 4. That Boucherised timber may be said to last ten to fourteen years. It would thus appear, that with those systems classed under the head of preservation by a salt, by which *moisture is contracted*, we have a varying and uncertain extension of the life of timber; but in no case is this extension such as to compete with that secured by creosote, by which *moisture is rejected.*

HORSE POWER OF BOILERS.

By W. BARNET LEVAN, Engineer.

The following trial of a boiler by evaporation and by Indicator diagrams was made August 5th, 1873.

The boiler supplied exclusively for this purpose belongs to an engine of the Cocheco Manufacturing Company, at Dover, N. H.

DESCRIPTION OF THE BOILER.

The boiler consists of a cylindrical shell, 16 ft. in length, and has a uniform diameter of 54 in., and contains in its lower half 80 iron tubes, each 15 ft. long and 3 in. external diameter, which are secured to the two heads in the usual way, and act as tube plates; the front head is set back 12 in. from the end of shell, to form a smoke chamber, the top of which has an outlet of sufficient area to carry off the products of combustion.

The brickwork forms a flue at the back end for the hot gases to pass from the furnace underneath and through the tubes, thence up the chimney.

There is a steam drum running parallel with the boiler, $8\frac{1}{2}$ ft. long, 30 in. in diameter, secured to the top of the shell by two 4-in. wrought-iron necks, 9 in. long.

The whole boiler, as described, is elevated 48 in. so as to allow for a furnace 18 in. in depth between boiler and the grate bars, and an ash pit 24 in. below the latter.

The following are its principal dimensions and proportions, viz.:

Total length in feet	16
Total length in inches	54
Total height in feet	8.66
Total number of tubes	80
External diameter of tubes in inches	3
Internal diameter of tubes in inches	2.75
Length of tubes in feet	15
Length of steam drum in feet	8.50
Diameter of steam drum in inches	30
Length of grate bars in inches	64
Width of grate bars in inches	56
Total grate surface in square feet	25
Heating surface in tubes in square feet	864
Heating surface other than in tubes in square feet	152
Total heating surface in square feet	1,016
Ratio grate to heating surface	1 to 40

THE ENGINE

Is one of Babcock & Wilcox's horizontal expanding condensing engines. The following are its principal dimensions:

Diameter of cylinder in inches	18
Length of stroke in inches	48
Diameter of air pump in inches (double acting)	10
Length of stroke in inches	12
Stroke of steam valve in inches	7
Number of strokes per minute	60

The cylinder is encased by a steam jacket, also the ends having free communication with the boiler, whereby the cylinder is maintained continuously at a high temperature. The bed or framing is bolted to the end of the cylinder, and extends to the pillow block, and the metal is so disposed as to give the greatest rigidity with the least weight. The cross-head is upright, and supported on flat sides, a drip cup cast on the bed serving to catch all drippings, not only from the slides, but from all the stuffing boxes.

In addition to the steam jacket for preserving the temperature of the cylinder, a covering of felt is employed around all the exposed parts, and this in turn is covered by a casting of polished metal; the latter being the best protection against loss by radiation.

The valves are four in number, having each a motion at right angles to the centre line of the cylinder, and are flat gridiron

slides, working on seats of corresponding form; the latter are made separate from the cylinder, so that they can be readily removed when necessary.

The motion is given to the expansion slides through an adjustable wedge-bar, moved by an eccentric, through a rocking lever in the usual way; the arrangement being such that the amount of lead, release, and compression, can be varied at pleasure while the engine is in motion. Each steam valve on the top side of the cylinder has in it ten openings disposed in two parallel rows, each opening being 1 in. long by $1\frac{3}{16}$ in. wide on the face. The distance between the openings are $1\frac{7}{16}$ in., so that when closed the bars of the valve lap the opening in the seat $\frac{1}{4}$ in. on each side, and the total movement required to give the valve a full opening is $1\frac{1}{16}$ in. The motion actually given is $1\frac{1}{8}$ in. The openings in the face of each admission valve terminates at the back of the valve in two parallel longitudinal openings or ports 10 in. long by 1 in. wide, and these are fitted with expansion valves moving parallel to the centre line of the cylinder and at right angles to the admission valves, which are moved by a small steam cylinder fitted with a piston parallel to centre of cylinder and controlled by the governor, the latter regulating the points of the stroke at which steam is admitted to the small cylinder in which the piston acting on the expansion slides works. The exhaust valves are fitted, as above, to ports at the bottom of the cylinder, and have but one row of six openings, these being $3\frac{3}{4}$ in. long and $1\frac{3}{16}$ in. wide on the face; the spaces between the openings and the motion is the same as the steam valves.

The spindles of the wedge bars for giving motion to the valves, are each coupled to a strap which encircles the corresponding wedge bar, and which is traversed by a pin carrying the roller on which the wedge bar acts. The motion of which is at right angles to that of the valves, and each is kept in its place by a cast-iron guide, which also guides the strap on the end of the valve spindle.

The wedge bars for moving the steam and exhaust valves are connected by a rod fitted with right and left-handed screws so they can be adjusted when in motion. The two steam wedge bars are connected to the upper and the two exhaust ones to the lower end of the rocking lever, and the direction of their motions are thus always opposite to each other.

The wedge bars are of cast iron and the slots faced with steel, the latter being $8\frac{1}{2}$ in. long, the stroke being 7 in.; this excess allows for adjustment. The length of the connections can be lengthened or shortened so the inclined portions of the wedge bars will act on the valve either earlier or later in the stroke; they all being independent, each valve can be properly set by the indicator while the engine is running. The independent steam cylinder which moves the steam cut-off valves is fitted with a piston valve which controls the admission and exhaust by being connected to the governor, admits steam to either end of this cylinder alternately, the point of the stroke of the engine at which the admission takes place, and at which consequently the expansion valve is caused to cut off the steam, being controlled by the position of the governor balls.

The ports through which the steam is exhausted from the small cylinder are so situated that the piston travels over them, and thus at each stroke a certain quantity of steam is shut in the cylinder and thus serves as a cushion to arrest the motion of the expansion valve.

The governor is peculiar and is shown in Fig. 3.

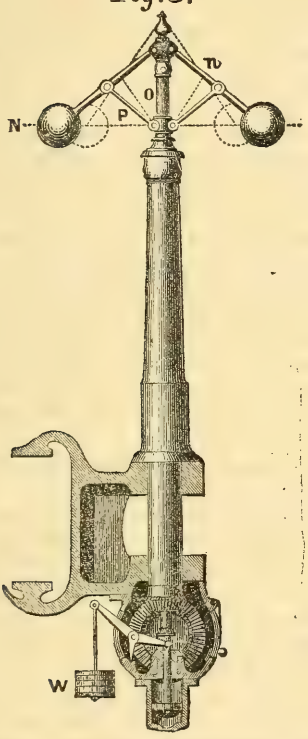
The balls, N, are hung upon arms in the usual manner, which arms are jointed at their upper ends to a head attached to the rod, O, which slides within the hollow shaft that drives the balls, the motion being communicated through the radius rods, P, which are jointed at their lower ends to the gearing shaft and at their upper ends to the centre of the arms, N. The rods, P, are half the length of the arms N, measuring from the centre of the ball, and it will be readily seen that in consequence of this arrangement the arms N, and rods P, form a parallel motion and compel the balls to move outward in a horizontal plane.

In the ordinary pendulum governor, the balls move in the arc of a circle and rise as they extend. It therefore requires an increased speed to maintain them in their advanced position.

The engine must consequently run faster when the load is light than when it is heavy, and such is the case with all ordinary governors. In this improved governor it will be seen that the gravity of the balls has no tendency to move them in either direction, and exerts

no influence whatever upon the speed of the engine. The centrifugal force causes them to diverge, and a weight, W, tends to bring them towards the shaft; when, therefore, these two forces are in equilibrium, the balls will remain in the same position, but as either preponderates they are moved in a corresponding manner, thus affecting the speed of the engine by varying the amount of cut-off. The weight, W, is supported upon a bent lever, which is so proportioned

Fig. 3.



that the centrifugal force at any given speed will just balance the weight in all positions. The speed of the engine will, therefore, remain at that fixed point with all variations of load or pressure of steam; for any increase or diminution will cause either the balls or weight to preponderate, and the point of cut-off to be changed, until the speed is again brought to the standard where the two forces are in equilibrium.

Any desired speed can be obtained by altering the weight W, and the action of the governor will be as perfect in one case as in any other. A spiral on the rod, O, serves to advance or retire the crank M, relatively to the main crank, so as to cause the cut-off to occur earlier or later in the stroke, as the balls diverge or converge, and the amount of this adjustment is such that the cut-off may be varied from nothing to seven-eighths stroke.

The standards which support the cylinder are hollow, and form a part of the condenser.

The air pump is bolted to the sides of the condenser at an angle of about 15 deg., and is worked direct from an eccentric on the main shaft. It is double-acting and is 10 in. in diameter, with a stroke of 12 in. The valves are india-rubber, and are arranged on gun-metal seats. The pump barrel, also, is lined with gun metal, and the air-pump piston is of the same material. The front head has the guiders cast fast to it, and is fitted with a cross-head to which is attached the air-pump rod and connections to drive it.

MODE OF CONDUCTING THE EXPERIMENTS.

The trial consisted in measuring the quantity of water evaporated and weighing the coal burned, and taking indicator diagrams every twenty minutes during seven hours. Fire was started under this boiler early in the morning of August 5, 1873, and the water brought to the usual height at 8 A. M., when the trial commenced. All the ashes were removed from the ashpit, and all the coal removed from the floor in front of this boiler. A pair of scales were provided and tested for weighing the coal and ashes.

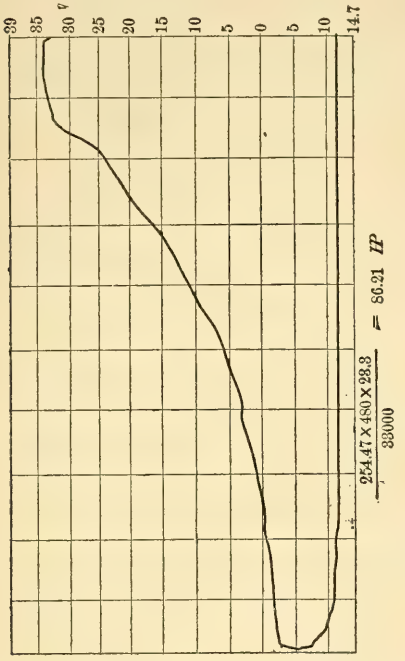
Total amount of coal consumed in pounds, was....	1,072
Ashes and clinker withdrawn from ashpit in pounds	31
Total amount of combustible in pounds.....	1,041

The quantity of water evaporated was measured in two wooden tanks constructed for the purpose, and connected with the force pump for supplying this boiler.

The tanks were 10 ft. long, 3 ft. wide, and 4 ft. deep; each tank had a rod plainly and accurately marked in inches, placed in the centre. Thirty-three inches in depth of No. 1 tank was evaporated, amounting to 142,560 cubic inches, and 37 in. of No. 2 tank, containing 159,840 cubic inches. The whole quantity evaporated was 302,400 cubic inches, equal to 175 cubic feet, at the mean temperature of 90 deg. Fah., or 10,856 lbs. A cubic foot at 90 deg. weighs 62.04 lbs.

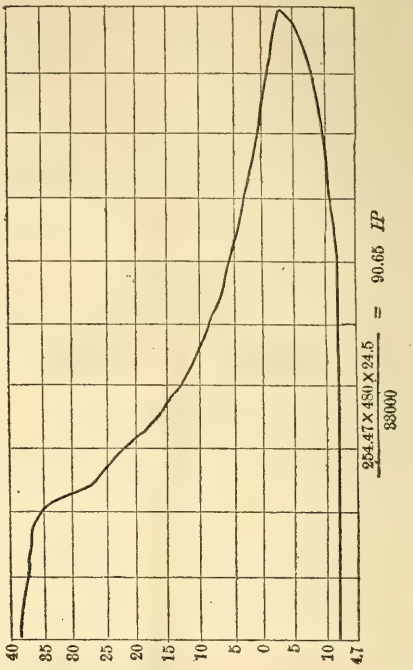
The coal used was a first quality of Lackawanna, a dry, free-burning anthracite, destitute of bitumen, burning without

smoke, and containing but little earthy matter, which was received in 1872, and under cover, giving a residuum of only *three per cent.* The quantity consumed was carefully weighed, as was also the waste in ashes in a dry state.

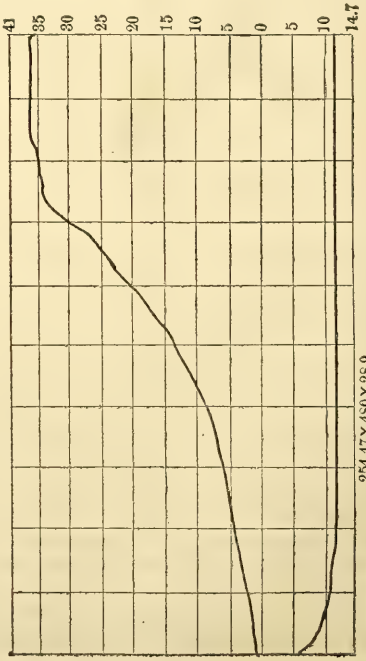


During the test the pressure of the steam per gauge, and its temperature, also the temperature of the feed water, and the product of combustion as they left the boiler, were taken every twenty minutes. The temperature of the feed water was observed in the feed pipe just before it enters the boiler, by a thermometer, the bulb of which was inserted in a hollow plug of iron, screwed vertically into the upper side of the feed pipe, open at the top and closed at the bottom, so that the lower portion of the plug was in the current flowing through the pipe; to insure the prompt conduction of heat, the cavity of the plug was filled with mercury. The steam pipe was arranged in the same manner. The advantage of this mode of applying thermometers is, that the thermometer is not exposed to pressure, as it is when directly inserted in the pipe, and in the event of breaking, no leak from the pipe ensues, and a new thermometer can immediately be substituted without interfering with the test, and the plugs, which are inexpensive, can remain in the pipe.

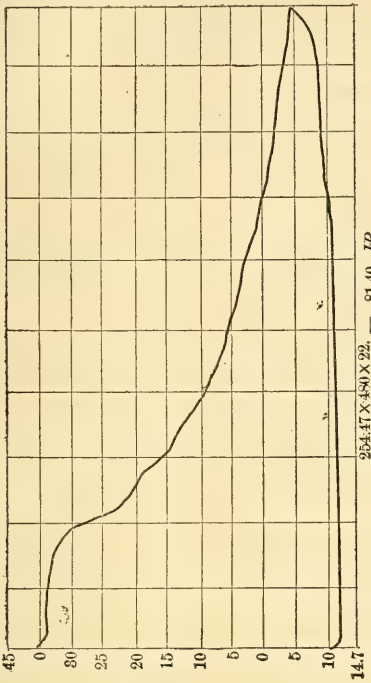
The steam pressure in the boiler was given by a large steam gauge. The temperature

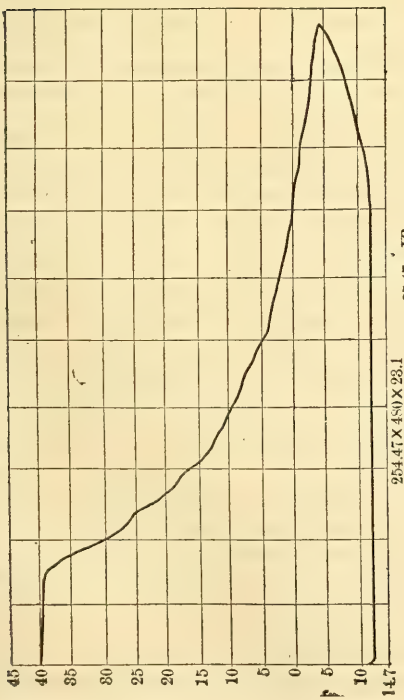


of the gases escaping from the boiler was also observed by a pyrometer inserted in



the flue about 12 in. from the boiler. The temperature of the air was also observed in several places.





The thermometers used are known in the trade as chemical thermometers; the whole instrument, including its porcelain scale, being inclosed in a glass tube; after the test they were carefully tested. The indicator used was an excellent instrument, and diagrams were taken from both ends of the cylinder. Average specimens of these diagrams will be found in cut.

Mean temperature of water in feed pipe in deg. Fah. 90
Mean temperature of steam in steam pipes " " 281
Mean pressure of steam in boiler in lbs. per sq in.. 39.9
Mean temperature of products of combustion deg Fah. 400
Mean temperature of air in boiler room in " " 87
Water evaporated from the initial temperature of 90 deg. by each pound of coal $= \frac{10856.09}{1072} = 10.12.$

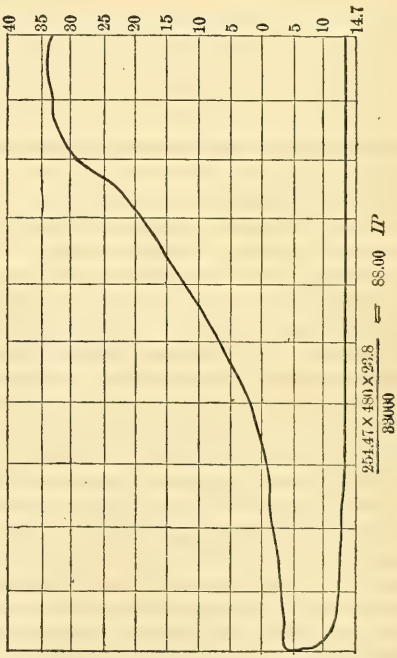
This reduced to the evaporation from and at 212 deg., by Rankin's formula, viz.:

$$h\ 2'\ 1 = 1092 + 0.3\ (T_1 - 32°) - (T_2 - 32°)$$

T_1 = the temperature of evaporation of saturated steam at 39.9 lbs. pressure..... 267.3
T_2 = temperature of the feed water in deg. Fahr..... 90.

Substituting the values of T_1 and T_2 we have the formula:

$$1092 + 0.3\ (267.3 - 32) - (90° - 32°) = 1104.59$$



which is the total heat per pound of water evaporated, this being the multiplier of the observed weight of water evaporated by each pound of coal burned, which, being di-

vided by 966, the latent heat of steam gives the weight of water which would have been evaporated by each pound of combustible, had the water been both supplied and evaporated at the boiling point corresponding to the mean atmospheric pressure,

$$10.12 \times 1104.59 \div 966 = 11.56 \text{ lbs.}$$

of water, had it been supplied and evaporated at 212 deg.

RECAPITULATION.

Total weight of water evaporated in pounds in seven hours	10,856
Total weight of water evaporated in pounds in one hour	1,551
Cubic feet of water evaporated in one hour	25
Average horse power per hour of 21 diagrams during seven hours	85

Horse power per cubic foot of water evaporated.

Horse power per cubic foot of water as per average of 21 diagrams feed water 90 deg	3.40

Coal per Horse Power.

Pounds of coal per horse power, per hour	1.80

Water per Horse Power.

Pounds of water evaporated per indicated horse power, per hour	18

Of the general performance of the engine and boiler tested at the Cocheco Manufacturing Company, it is unnecessary to mention, as the figures I have given speak for themselves.

The results are, however, additional proofs of the advantages which are to be derived from the employment in mills of first-class engines for furnishing the motive power.

The above results were obtained with low temperature feed water for the convenience in making the test.

In their every-day practice, the feed is drawn from the hot well, and is passed through a heater, which increases its temperature nearly to the boiling point before it enters the boiler, the result of which being a still greater economy.

FIRE-PROOF CONSTRUCTION.

From "Iron."

It is not many years since the literary world was at once entertained and instructed by the publication of a book entitled "Fallacies of the Faculty," wherein false pretensions of divers kinds were ruthlessly exposed as by an anatomical process, with a keen insight and an unsparing hand. It is not only in the "Faculty," however, that there are "Fallacies;" and every now and again comes some startling calamity, to test and, as it would seem, to expose, through the ordeal by fire, false pretensions and fallacies in Construction, so-called fire-proof. Of this class is the tremendous conflagration at the Pantechnicon, which occurred on Friday last, in the very centre of Belgravia —the focus of fashion—withering up with its fiery breath, not only an amount of property valued at an enormous sum, but also what is or should be of far greater consequence, namely, an unthinking and unenlightened confidence on the part of the public in the resources of the building art, as against the ravages of fire; which, were it well founded, would be of immense importance, but which, being or seeming to be fallacious, has been and is, productive of grave evils.

To be the Cassandra of the press is to fill a thankless office; such functions, therefore, are rarely lightly assumed, and generally quickly, perhaps too quickly, set aside; nevertheless, at critical periods, in the continued presence of an ever-nascent risk, and more especially when some violent outbreak —such as of that faithful servant, but awful master, fire—comes to point the moral, it becomes a duty to turn to account the opportune text, even to reiteration, in season and out of season, of unwelcome truths; to show, as far as possible, what may be deemed fallacious, and wherein reliance, if haply such there be, may be placed.

It is needless, nay, useless, to appeal to recent experience in other countries; to point to Boston and Chicago, for instance, inasmuch as cases are altered by circumstances, which, for the matter in hand, mean modes and materials of construction. It suffices briefly to recall attention to the facts of a few large conflagrations in this city and country, of comparatively recent date—the burning down of country mansions, Canterbury Cathedral, the Alexandra Palace, and various metropolitan fires, which scarcely need particular identification by name—to justify the broad statement that all methods and materials of construction, as hitherto practised and employed, have failed thoroughly to realize the

desirable quality of being absolutely fire-proof; there are, doubtless, various combinations of certain well-known materials, such as iron, stone, and brick, to the entire exclusion of wood, which profess to be, and pass for being, fire-proof, a quality which, to a greater or less extent, they possess, but only in comparative degree; whereof the proof is found in the fact that, whereas they may withstand the test of the ordinary run of fires, yet they fail ignomoniously to pass unscathed through the fiery baptism of any conflagration of exceptional magnitude; and there can be no more remarkable illustration of this inherent weakness than the "Pantechnicon" itself, wherein every possible precaution had been carefully studied and adopted, every combustible material rigidly avoided and excluded, every fire-proof or presumably fire-proof material, carefully selected, lavishly employed, and skilfully combined—resulting only in complete and utter failure under the crucial trial.

Such failure, however, is by no means so surprising as the original confidence; for it is only to the superficial and unscientific observer that iron and stone, unprotected, assume the semblance of fire-proof materials. The expert knows that stone crumbles away, and that iron warps and buckles, nay melts, under the action of fire, more particularly when the agency of water is brought in contact therewith; so that, as a matter of fact, a sound beam of oak is more reliable than an iron girder or column. Good brickwork certainly approximates most nearly to the desideratum of fire-proof construction; but it requires to be very massive and well put together; as, otherwise, mortar perishing with heat, the coherence of the mass is apt to be destroyed by fire, so that, though an arch might stand, a wall might fall.

Is the conclusion, then, inevitable, that there is no such thing possible as thoroughly fire-proof construction? Not so; the proper corollary is simply that the failure lies, not so much in the materials themselves as in the manner of their use and the method of their combination; and herein lies the secret of success, that the wood, iron, stone, or brick, should be covered, isolated, and protected by special means and appliances. As for example, there are special fire-proof paints, which will, at least, go far towards protecting woodwork superficially; just as, also, it may be made uninflammable by "mineralization," or filling up the pores and fibrous interstices with particular ingredients. Similarly a coating of plaster is found to act materially as a preservative for iron against the destructive action of fire. We refer to these, not as being in themselves fire-proof expedients, but as subordinate elements in a system of fire-proof construction; and more particularly as the principles involved have really been practically embodied in a special invention of a method of construction which we have previously described, and at intervals referred to. And having no other interest in the matter than the general good, and a desire for the prevalence of sound doctrines, we have no hesitation in making farther brief notice thereof; more especially as it has quite recently been adopted as a preservative and precaution against fire by one of the most prominently known of capitular bodies, under the advice of one of the most eminent of English architects, in one of the largest and most noted of metropolitan public buildings—St. Paul's Cathedral.

Startled into the consciousness of latent but ever-present danger, by the catastrophe at Canterbury Cathedral—in itself only a repetition of similar preceding disasters, such as those at York Minster, on two occasions, and others perhaps not quite so well known—the Dean and Chapter of St. Paul's Cathedral, solicitous to leave no stone unturned to secure the noble fane which is their anxious charge, called to their councils Mr. Penrose, who is their architect, with an especial view to the protection of the interior woodwork of the dome. In brief, the result of Mr. Penrose's researches and inquiries has been that an efficient fire-proof lining has been provided for the same, which has just been completed by Mr. P. Brannon, C. E., of Parliament street, Westminister, upon his patented principle of construction.

Mr. Brannon's mode of construction consists in the employment of webs of iron wire, angle-iron ribs and framing, and the like, combined with a peculiar fibrous concrete of filamentous materials, with cement, gravel, or old bricks and rubbish, the whole concreted together and compressed into a fabric of great strength, perfectly unaffected by fire; wherewith may be constructed in any desired form and thickness the entire component parts of a building, whether dwelling house or other, such as walls, flat floors, ceilings, and roofs, chimneys and

flues, stairs and doors. The advantage of this principle and method of construction—apart from its quality of being perfectly fire-proof—is that it is not merely a special and expensive device, suitable only for large and costly buildings for purposes of trade, commerce, and industry; but that it is economical and perfectly adapted for the building of a cottage, a shop, or a dwelling house, upon a small or a large scale. In fact, such houses and cottages have not only been built and inhabited, but absolutely tested by conflagrations, of combustible substances piled up therein and ignited—without the slightest injury and detriment being the result—the ravages of the fire being strictly limited to the space contained between the walls and doors, floors and ceilings, without spreading or communicating in any way from one room to another, upward, downward, or laterally. Now, although in relation to the behavior of such a material, and the resisting powers of such a building, in the ordeal of a tremendous conflagration, there can be nothing more than fair presumption, until chance brings about such a thorough test; yet, so far as such a thing is practicable, there is *prima facie* evidence of a favorable and satisfactory result. Hence Mr. Penrose's investigation having brought these facts, unsolicited, to his knowledge, has resulted in the adoption of Mr. Brannon's principle for the protection of the timbers in the dome of St. Paul's Cathedral, as mentioned.

The manner in which this work has been carried out is peculiarly suggestive of what may be accomplished towards the attainment of effectual security against the hazards of fire, in the case of existing structures. The first portion dealt with has been that section of the inner and outer domes through which passes the approach to the highest gallery, and the ball, which is therefore most exposed to risk, as being accessible to the public. In this portion, which comprises five compartments, situated between two of the flying buttresses, the whole internal surface has been completely covered with fire-proof casing, formed of the patent stone felt, surrounding the whole of the woodwork, with air space between, maintained by the insertion of isolating blocks of stone felt with insulating washers of alumnized felt, through which pass the screws or other means of attachment to the wood. Externally the fire-proof casing is made ornamental by being worked in panels, and the connections with the stonework are suitably made perfect. Panels, for the inspection of the exterior dome, and doors of partition, made of the same fire-proof material, are provided and fitted with fire-proof rabbetings and weatherings, so that the whole compartment is entirely insulated from those adjoining on either side. Similarly the wooden steps, treads, risers, and landings have been covered with fire casing, so that, in fact, there is absolutely nothing for the flame to get hold of, or be nourished by. It is difficult to conceive any protection which should be more complete and effectual for existing structures.

THE IRRIGATION WORKS OF INDIA.

From "Engineering."

There can be no doubt whatever that in former times under native rulers of India large tracts of country were very extensively irrigated. Commencing with the basin of the river Indus and the Punjab, there was an extensive system of well irrigation and of inundation canals. The district of Multan, between the Sutlej and the Chenab, where rain hardly ever falls, was a succession of beautiful gardens, shaded by date palms, the corn and fruit abundant; the Afghan rulers, left by Aurunzeb, developed this to such an extent, that one of them cleared for himself from them a private fortune of nearly a million pounds sterling. There were also other inundation canals in Gugaira and other districts of the Bari Dooab above Multan; of these the Kanwah and Sohag canals are best known, and a more complete system in the rich country of Muzaffargarh, between the Chenab and the Indus, the land under the influence of which was one sheet of cultivation. In the Shahpur district there were several inundation canals drawing their supply from the Jhelum. In the Derajat, on the right bank of the Indus, there were 12 inundation canals, having an aggregate length of 291 miles, running parallel to the Indus, and filling themselves from it in the periods of annual inundation. The native State of Bahawulpur, on the south side of

the river Sutlej, was also partly irrigated by inundations. In fact, in former times such canals were conducted from all the five rivers of the Punjab, traces of them, and the ruins of cities and villages on their banks, being still visible; ravines and water-courses of small rivers or their branches, that are now dry, or have had water diverted from them either by natural processes, or by want of repairs or proper maintenance, were formerly used for conducting water for irrigation, which was then raised from them on to the fields by means of Persian wheels. It is, of course, quite impossible to determine the acreage then under irrigation; it was probably a very high percentage of the cultivatable area; but there is no doubt that some of these canals were large, notably those from the Chenab, named the Minchinwah, Barus-wah, and the Sadik-wah, which were channels 100 ft. to 200 ft. wide. The immense numbers of ruined canals of different sizes all over the Punjab and Bahawulpoor, cannot fail to produce to the imagination a most flourishing and populous country of the past; and when, too, we find that these natives kept also their towns well supplied with water, fountains, tanks, and baths, as may be discovered by examination of traces and old ruins in Lahore, Amritsir, Delhi, Kurnal, and countless other towns, we cannot but feel mortified as well as astonished at the inferiority and paucity of similar results under British rule.

In Sind, the country lying on the lower 450 miles of the river Indus, inundation canals were formerly both numerous and important; they varied in size up to 100 ft. in width, 10 ft. in depth, and 80 miles in length before branching off into smaller canals. Those positively known to have existed on the western bank of the Indus are as follows: The Sind Canal, having its off-take 21 miles below Sakkhar, 66 miles long, before dividing itself into three branches, the Mutti, the Kadu, and the Mihshuda. The Ghar or Larkhana, leaving the Indus 23 miles below Sakkhar, and having three heads or channels of supply; this is very tortuous, and eventually divides itself into two canals, the Nurwah and the Nowrung, which again sub-divide themselves. The Western Nara Canal leaves the Indus 27 miles below Sakkhar, and returns to it at Sehwan; at 40 miles from the head it is 200 ft. to 300 ft. wide; the country is well cultivated on either side of it and the villages are numerous. The Bigari Canal had a total length of 48 miles with a fall of 35 ft.; the head was on a side channel, 7 miles from the Indus; it was 24 ft. wide and 9 ft. deep at the head in 1844, but then much reduced from its original size. For the first 23 miles it passed through a country covered with scrub, but presenting frequent traces of former cultivation; for the remainder of its course water was taken from it by means of Persian wheels; its principal branch was the Nurwah Canal, entering far into the desert north of Khangarh.

On the eastern side of the Indus, the principal ancient canal was the Eastern Nara, called the Puraun in its lower course; it irrigated a large tract of country, part of the great Thar or Indian desert, sometimes spreading itself into lakes, of which there were as many as 400. There was also the Fullali Canal, the main feeder of irrigation channels from Haidarabad southward and eastward; originally it was a natural branch of the Indus, joining it again at a point 16 miles below Haidarabad, but the Amirs diverted the water by a dam, sending it to supply the Gaja, the Guni, and other canals to the south; the chief portion thus fell into the Guni after a course of 40 miles, the average width being no less than 350 ft. In the North-West Provinces, or what is called Hindustan proper, the Emperor Firuz Shah constructed the Western Jumna Canal, conducting water to Hissar; a branch from this to Delhi was made by Ali Murdan Khan, under the order of the Emperor Shah Jahan, in 1626; it crossed the lowland by a masonry aqueduct, crossed the Aravalli hills in a rock-cutting 60 ft. deep, and flowed through the city in a masonry bed, throwing off innumerable smaller streams. The great halls and courts of the palace, the fountains, marble baths, reservoirs and gardens, were supplied by numerous channels from it. This state of things lasted for 150 years until the year 1753. Ali Murdan Khan also constructed another canal in the Dooab, east of the Jumna, under the Emperor Shah Jahan in 1650; it was neglected and fell into disrepair, but was restored in 1764 by a Rohilla chief, Zabitha Khan. In the neighborhood of Delhi is a chain of natural lakes or jhils, the principal of which were the Najafgarh and the Kotida; these, collecting the drainage of the slopes from Delhi to Budshahpur, were formerly em-

ployed in the irrigation of the country around and below them.

Besides these works, an examination of the ruins of Old Delhi, better known as Toghlukabad, about 10 miles from New Delhi, or Shahjahanabad, shows remains of a canal, of extensive reservoirs, made or walled with concrete and cut stone, and undoubted traces of a complete system of irrigation and water supply. The magnificence of the beautiful ruins of immense tombs, mosques, palaces, halls, markets, and pleasure gardens with fountains and water channels in exquisite taste, prove that this must have been on a large scale. A careful examination of the whole of the portion of country on the right bank of the Jumna below Delhi, and a certain part of that on the left bank, shows that there must have been an immense number of tanks or artificial reservoirs, probably one or two near each of the large villages, from which irrigation was carried out. The traces of these are for the most part entirely obliterated, but enough remains to show what must have been the state of the North-West Provinces as regards irrigation under native rule. In Rohilkhand water was collected by damming up the hill streams, and leading small canals from them over the country; in 1824 there were 1,930 dams and 915 canals; all the country between the Ramgunga and the frontier of Oudh is intersected by hill streams, from whence canals could have been, and probably were led. As to Bundalkhand, there is no record of what was done in the olden time, though probably a careful examination by an experienced hydraulic engineer might discover many traces of irrigation.

In Rajputana large reservoirs still exist; others have gone to ruin, and barely show their traces; these are more especially in Jaipur, Udaipur, Jesalmir, Bhurtpur, and Alwar. As to the large province of Bahar and Upper Bengal, there are unfortunately no records of former native irrigation; the province of Orissa, inhabited by a particularly slow and indolent race, probably had comparatively little native irrigation. The forementioned provinces may be said to comprise the whole of Northern India; Southern India, which includes everything south of the Vindhya Range, or the general latitude of the courses of the rivers Narbada and Mahanadi, has features peculiar to itself as regards irrigation, depending on the general formation of the country. This, consisting generally of large plains having a very gradual fall from the Western Ghats to the Coromandel, admitted of tanks and reservoirs being made on a very large scale; these are therefore very numerous in certain districts, and occasionally are very large. Taking the provinces in order going southward from the Narbada, the Central Provinces and Berar have a comparatively small number of old works of irrigation, although a fair number of ruined tanks of a small size still exist, and there are undoubted traces and traditions of some few dams. The towns of Akola, Ellichpur, Burhanpur, and others, were once well supplied with water. In Nimar, Kandeish, and the Bombay Presidency there were still fewer of these, the falls and form of the country being unfavorable on the whole, the rivers having but a slight slope, and the transverse slopes of the valleys being so great as to prevent canals from them from getting to a sufficient distance from the parent stream. In the large native State of Haidarabad, the eastern and southern portions have a large number of tanks, some of them rather large. The city of Haidarabad has a large artificial lake, called the Hosen Sagar, close to it, and the city of Aurungabad has the remains of a very extensive system of water supply, the water for which came from several distant sources; of this, one channel driving a very primitive turbine and supplying a large fish pond, still exists. In the fourteen districts of the Madras Presidency there are 43,000 native tanks, with about 30,000 miles of embankments, yielding a revenue of one and a half million pounds sterling, yet up to 1853 the English had not made one, although many had been allowed to fall into disrepair. The number of tanks in some of these provinces is thus given in the "Progress Statement" for 1873.

Visagapatam	26
Godavari	?
Krishna	39
Nellor	116
Karnul	15
Ballari	114
Kadapa	75
North Arcot	477
Salem	91
South Arcot	218
Coimbator	29
Trichinapali	85
Tanjor	64
Madura	115
Tinnavelli	522
	1886

This table barely accounts for two out of the forty-three thousand mentioned; the remainder possibly being in Mysor, Haidarabad, and Travancor. In Mysor there must have been a very large number of them besides these; the waters of the rivers in Mysor were utilized by means of dams and channels. Some are very large; the Viranum tank has an area of 35 square miles, and a dam 12 miles long; the Chembrumbakum tank has a dam 3 miles long, and irrigates 10,000 acres of rice cultivation; the Kaveri-pak tank has a stone revetted dam 4 miles long, and irrigates 7,700 acres.

In the Krishna district there is a dam of stone 3,750 ft. long, and 305 ft. broad, with canals from it on each bank; the English acquired the Krishna delta in 1766, and did nothing for it for 80 years, while famines periodically devastated the land; in 1833 not less than 200,000 people, out of about a million, died of hunger, and the Government lost nearly a million pounds sterling of revenue. In the Balari district the rajahs of Tizianagur constructed dam and canals from the river Tungabudra in 1521, nine dams, and 89 miles of canal; the city of Vizianagur with its suburbs was formerly also plentifully supplied with water. The great Kaveri dam, of solid stone, 1,080 ft. long and 40 ft. broad, was constructed 1,600 years ago. In Tinnavelli there were formerly a large number of dams and canals from the river Tambrapurni, many supplying tanks.

In giving the above account of native works of irrigation, it must be remembered that those alone have been mentioned of which there is positive record; it is probable that there were formerly very many more of which the memory and the traces have entirely passed away; enough, however, have been rediscovered and mentioned above to prove that in former times, and under native rule, India was on the whole plentifully and well irrigated. The works were probably clumsy, slovenly, and defective according to our ideas of engineering, but they were efficient in irrigating the land, producing food, and supporting a population that, had it not been for civil and political discord, must have been in a highly prosperous condition.

MODERN IMPROVEMENTS IN ARTILLERY.*

By Capt. E. SIMPSON, U. S. N.

Says a military writer, in summing up an official report on the naval equipment of European countries: In considering the foregoing report on the artillery of England and other European countries, the first and most important feature to be noticed is, that it consists almost entirely of rifled cannon. Some smooth-bored guns are yet in use, but they are simply retained because the conversions in progress and the new constructions have not yet been able to supply a sufficient number of rifled guns to replace the smooth-bores, now considered obsolete. It will be remarked that, in all countries reported on, great activity is apparent in the arsenals, in order to complete the reform universally acknowledged to be necessary.

Apart from the increased range and accuracy due to the rifled system, the introduction of iron armor for ships and forts is a sufficient explanation of the cause of this change in the character of the artillery, as it has been conclusively proved that, in order to operate against the new defence, a radical change must be made in the character of the attack.

The experience of the United States Navy during our late Rebellion, showed that, even against our poorly-armed monitors, the effect of 11-in. smooth-bores was not serious, and these guns would be totally ineffective against the better-armored vessels of the present day. When wooden walls were the only defence at sea, no gun was superior to the Dahlgren 11-in. smooth-bore; but the new character of defence robs it of its power, and as it constitutes the heaviest armament of our cruising vessels, it is evident that against armored vessels we are harmless for injury. The necessity of a change in armaments, recognized by all the world except ourselves, must force itself upon the mind; unless we can believe that it is possible for us to be right, and all the rest of the world wrong, which, in view of the intelligence and

* Report on a Naval Mission to Europe. Washington: Government Printing Office.

ability displayed by European artillerists, would be a presumption difficult to establish.

Premising that the necessity of a change in our naval artillery is recognized, it remains only to carefully select from foreign systems what may be considered the best, and either to adopt it as a whole, or with such improvements as the latest experience may suggest. There is no doubt that, at the present time, we find ourselves in a most favored position for coming to a judicious conclusion on this subject, as we are at liberty to take advantage of the results of most exhaustive and expensive experiments, which have been carried on by foreign powers; and, in considering the subject, and weighing one system against the other, our minds are free from any national bias, and are not likely to be influenced by prejudice. Each Government which has originated a system is naturally wedded to its own invention, and looks through a distorted medium at that of a rival power; while a Government uncommitted to any system, is free to detect flaws and to recognize perfections.

Before deciding upon a system of construction for the new artillery, the first point to decide is whether the gun should be a breech-loader or a muzzle-loader. In reviewing the foregoing report, it will be seen that in all countries of Europe, England alone excepted, the breech-loading systems of Krupp, and that adopted as the French system, are recognized as being successful; thus the question as to the practicability of carrying out the project is solved, and any unprejudiced mind must acknowledge that a breech-loading cannon is a success. The success of the system of breech-loading is demonstrated for all calibers, the most formidable cannon in Europe being of that construction. The practice in England, so persistently quoted by the enemies of the breech-loading system, is alone opposed to the introduction of a breech-loading cannon; but there is reason for this. The English artillery is founded upon the system of construction introduced by Sir William Armstrong, and the original invention of Armstrong involved the principle of breech-loading, and had his system of breech-loading proved as successful as his system of construction, there is no doubt that the artillery of England would be breech-loading to-day; but experiments proved that the breech-loading system of Armstrong was very defective, and after much money had been expended in a blind effort to make it practicable it was definitely abandoned, and the fault of the *system* was charged to the *principle*, which was declared to be impracticable, and was thrown aside, and the muzzle-loading principle was retained. Here is an instance of a prejudiced adherence to a national invention. No efforts of a system from abroad, although the English mind was ready to embark in the breech-loading system; it was sufficient that the English invention had proved defective, and this fact blinded the eyes of the Government to the advantages possessed by other systems. The Government committed itself entirely to the muzzle-loading system, and the plant at Woolwich was accordingly established with a view to the sole manufacture of that species of gun. It would require now a most powerful demonstration of the superiority of the breech-loading gun to induce a change in the English system, but the minds of many of the most enlightened artillerists in England are impressed with the success of the system abroad, and recognize its advantages.

The struggle between the breech-loading and the muzzle cannon is much the same as that which existed between the breech and muzzle-loading small-arm not many years ago. The arguments made at that time against the introduction of the breech-loading musket are again repeated in the case of the cannon, yet no nation would now consider Brown Bess as a weapon fit for her infantry, and the breech-loading cannon must, in turn, be considered equally necessary for the use of artillery in the field or for the armament of ships of war.

For the latter purpose, the breech-loader presents so many advantages that it is somewhat remarkable that the necessity for its introduction on shipboard is not more readily appreciated. The facility of manipulation, the increased projection from the port, the protection to the gun's crew, are all points of most vital importance; and the piece, even after the bore is badly deformed, recommend it as a system promising the most happy and reliable results in the day of trial. The chief point that objectors raise to the system is the want of safety—so claimed by them. But the result of years of experiment and practice, both with the French and Prussian systems, goes to show that this objection has no foundation in fact, and the experience of actual war-

fare is not wanting in order to prove that this apprehension has been dissipated.

In determining upon a system for *construction*, the prominent plans to be considered would be the following:

The Woolwich gun (Fraser's).
The Vavasseur gun.
The Krupp gun.
The French gun.

In connection with these, as original constructions, there would have to be considered the following systems of conversions, viz.:

The Parsons converted gun.
Pallisser's converted gun.
The Dutch converted gun.

To which would be added a consideration of the plan proposed by Mr. Bashley Britton for utilizing as rifled cannon the stock of cast-iron smooth bores, so as to make them efficient for the secondary purposes of artillery.

The Woolwich gun is made of wrought-iron coil, lined with a steel tube. It is thus composed of two metals, differing widely in their characteristics. The malleable character of the wrought iron is inconsistent with the elasticity of the steel, and repeated firings have the effect of separating the surfaces, by which means the steel tube becomes, in time, unsupported, and cracks.

The use of the steel tube, however, is found to be indispensable, as wrought iron is pronounced to be unfit for the bore of a gun of large caliber, burning a large charge of powder. The gun is styled a wrought-iron gun, and the metal of the tube is always blamed when the gun comes to grief; yet it is found necessary to use this metal, which is acknowledged to be an element of weakness and uncertainty in the construction. That this is so there can be no doubt; not, however, on account of the fault of the metal, but because the metal is not properly supported.

The Woolwich construction results in a very safe gun, but one which must be classed as short-lived, being deficient in endurance. The gun is safe after the tube is split, as has been often proved, but it cannot be considered as fit for service when in such a condition; hence the lifetime of the gun must be marked to the time of the cracking of the tube.

The Vavasseur gun is constructed with a steel tube of the same proportions as that of the Woolwich gun, but the body of the gun is built up of steel, thus giving a support to the inner tube of the same metal of which it is composed. There is a homogeneity throughout the wall of the piece, which results most favorably for the support of the tube. This gun is probably the most theoretically perfect construction that is in use, and the results of practice, so far as they have extended, go to prove the correctness of the principle. In the appendices of this report will be found reports by English and French artillerists on a 7-in. gun of this construction; and guns of larger caliber in battery at Callao, Peru, were found to be very formidable pieces by the Spanish fleet during their attack on that place.

The gun is made entirely of steel. The inner tube is entirely inclosed from breech to trunnions by a long jacket of steel, shrunk on, and constituting a constant reinforce. This is in turn reinforced by steel bands shrunk on, one or two layers, according to the caliber of the piece; and the chase of large pieces is also reinforced in like manner. The jacket is shrunk on lightly, the outer hoops at a great tension. The object of this is to force the inner tube to assist to its utmost in restraining the force of the charge before calling on the supporting parts for aid. The mutual support given by all parts in this construction is most perfect, and there can be no doubt of the wisdom of adopting such a system of artillery as this.

The Krupp gun is also of steel, but differs from the Vavasseur gun in the mode of construction. The reinforcing jacket used by Mr. Vavasseur, which is required to give longitudinal support to the thinner tube, is dispensed with, and the hoops are shrunk immediately on the tube, which is thicker than in the Vavasseur gun. The present Krupp construction is a change from its original mode, in which the entire wall was a solid casting, and he adhered to this practice until experience proved the necessity of *building up*. The modifications made from time to time in his construction have been gradual, but he constantly finds himself forced to approach the system of building up as practised by Mr. Vavasseur. The tube is still much thicker, and he has depended on the thickness of the solid tube to supply all the strength required for the chase of the gun, even though he now builds up on the reinforce of all calibers; but from late experience in Russia with a Krupp 11-inch gun, it is evident that the

chase must be built up as well as the reinforce, as, in the case referred to, the chase of the gun was ruptured.

Building up on the chase will be the commencement of the reduction of the thickness of the tube, which will be another approach to the Vavasseur type.

The French gun is a cast-iron gun, strengthened on the reinforce with steel hoops. There is no doubt that the gun proper is much strengthened by the inclosing hoops, as the effect of their compression is appreciable in the difference of the diameter of the bore before and after the shrinkage of the hoops; but it would be impossible to obtain the same strength or endurance from such a gun as from a scientifically constructed steel gun in which the tensile strength of the metal is much better, and in which the actual strength is increased by the elasticity of the material.

The Pallisser converted gun is a cast-iron gun lined with a tube of wrought iron. As it has been shown that wrought iron is entirely unfitted for the bore of a gun of large caliber, it is evident that the use of this conversion must be limited to small calibers, and even though these small caliber guns are considerably strengthened by the introduction of the wrought iron tube, yet the charges of powder used in them are not such as to warrant their being classed under the head of high pressure-guns for use against armor, but they must be always limited to the secondary uses of artillery, for which purposes the old cast-iron smooth bores, simply rifled and firing elongated projectiles, as proposed by Mr. Bashley Britton, would be nearly as effective.

The Dutch converted gun is the same as the Pallisser's, substituting bronze for the coiled wrought iron tube. All the objections to wrought iron for the tube of a gun obtain to a greater degree in the case of bronze, limiting a gun converted on this system to small calibers and a small number of fires, as the scoring that would take place in the bore would soon reduce the rifle-practice to a low standard of precision.

The only remaining gun deserving of note is the Parsons converted gun, which combines strength and endurance with cheapness when compared with other guns which give as good results. The main construction is the same as the Vavasseur gun, being a steel tube reinforced with a long jacket of steel; but Mr. Parsons dispenses with the exterior hoops of steel, and inserts his reinforced tube into an outer casting of cast iron, which supplies all the necessary strength for the exterior, and affords an opportunity of utilizing the cast-iron guns on hand. The experiments made in England and France with two guns, converted by Mr. Parsons, are recited in this report, and they show that no guns have ever exhibited more satisfactory proof of endurance. In closing this report, then, and after a careful study of all the systems in Europe, I would recommend the adoption of the Parsons system of conversion, combining with it the breech-loading arrangement of Krupp (or Broadwell) with the Broadwell ring for a gas-check.

In reference to projectiles the selection would rest between the adoption of the Prussian lead-coated projectile, and that patented by Mr. Vavasseur, and now adopted in France, in which there are inserted in the cylindrical part of the projectile two more rings of soft copper. In the former case, oxidation is said to destroy the close fit of the coating, although it is also claimed that the new method of soldering on the lead with zinc obviates this difficulty. No objection presents itself to the copper-ring system, which has been successfully experimented on by the French with their largest calibers.

The studded projectile is to be avoided. As used with the Woolwich gun in a gaining-twist, the effect of the passage of the projectile along the bore is to shear the studs, causing them to ride upon the lands, which might be attended by most serious results to the gun. The use of the studded projectile with a breech-loading gun results in the abandonment of most of the advantages to be derived from the breech-loading system. This projectile, long in use with the French breech-loader, is now abandoned, and the copper-ring projectile has been substituted, which develops the advantages of the breech-loader in giving increased range and accuracy, with less scoring of the bore.

The official report of the Vienna Exposition shows that England produces more than one half of the iron production of the world, North America about one-fifth, France about one-twelfth, and Belgium one twenty-fourth—these four constituting the great iron-producing countries of the globe.

ON SIMPLICITY AS THE ESSENTIAL ELEMENT OF SAFETY AND EFFICIENCY IN THE WORKING OF RAILWAYS.*

By Captain HENRY WHATLEY TYLER.

From "Journal of the Society of Arts."

The various classes of collision, and the accidents at facing points, may together be roughly stated to comprise from two-thirds to three-fourths of the casualties to railway trains which are considered of sufficient importance to require investigation on the part of the Board of Trade; and questions as to the arrangement and working of points and signals, and as to preserving intervals of time or space between trains and their accessories, enter more or less into the causes of such casualties. In 1872 there were 179 such accidents out of 238 investigated train accidents; in 1871, 105 out of 159; in 1870, 97 out of 122.

Within the ordinary limits of a paper of this description it would be neither desirable nor possible to enter into all the details of the apparatus employed by the different railway companies for points, for signals, and for train-telegraph purposes, or to discuss all their relative merits or defects. Such a description would, if complete, fill volumes; and in such a discussion it would be very difficult to deal, as the author would always desire to do, in perfect fairness with all competitors. It would seem to be preferable and more useful to put forward in this paper the principles involved, the requirements to be satisfied, and the direction in which further improvements may be effected. It is only by close attention to the constant teachings of practical experience on various systems of railways that the present degree of perfection has been reached; it is only by patience and perseverance in the same method, under the same instructor, that further advances in real improvement can be made; and it is only by the full application, proper working, and careful maintenance of the necessary appliances, that their due result in the diminution of railway casualties can be obtained.

There is, perhaps, hardly any subject in regard to which there has been more misunderstanding, or greater confusion of ideas, than simplicity in railway working. The author and his colleagues have constantly been accused of requiring complication when they have been seeking to introduce simplicity; and in adopting, for this reason, the heading of the paper as his thesis on the present occasion, the author would say a few words at the outset as to what is and what is not simplicity in such matters. It is, or ought to be, the object of the inventor or engineer, in his designs or his projects, his schemes, his plans, or his work. It is usually the last result which, after the greatest amount of thought, is attained. The same is true in other fields of work. Even in literary labor, perfect simplicity of diction, of description, of argument, requires the greatest thought and care, and is the most difficult result to arrive at. The Latin words *simplicitas* and *simplex* convey, no doubt, the idea of singleness—of one thing; and a simple machine is in the same sense a machine of few parts, while a complicated machine is a machine of many parts. But simplicity of construction and simplicity in working are in many cases distinct and different from one another; and, further, complication in construction is frequently necessary to obtain simplicity in working. This is equally true of a machine, of a railway, or of a sentence. Simplicity in working, as desirable, being the thesis, confusion in working, as undesirable, is the opposite idea presented for consideration in the present paper. As a confused sentence can sometimes only be made plain by dividing it into a greater number of parts; and as a machine can only in many cases be started and stopped, and made to work more easily, by adding to its parts in construction,—so also a railway may be worked more simply, with less confusion, more efficiency, and less risk, by the addition of certain appliances and accommodation, and by their proper adaptation to local circumstances.

Ingenuity, care, and forethought are required in their application, and time and experience for their development and further improvement. Railway working, which was at first easily conducted, is becoming a science, with its separate branches;

* A paper read before the Society of Arts.

and the author aims at no more in the present paper than an outline sketch, which he hopes may be filled up by a full discussion. He ventures to think that the time has arrived for such a discussion, and to hope that full latitude may be allowed for the expression of opinions from all classes and all parties interested in the subject.

The first important branch, then, of railway working to which reference may be made, is that of points and signals. When trains were few, and there was little risk of their interfering with one another; when they had the same regular stoppages, and the speed was not great; when junctions, stations, and sidings were less frequent,—then fixed signals were comparatively unimportant, the switches did not require to be so often moved, and facing or meeting switches were not the cause of so much risk. When the want of fixed signals was experienced, boards and lamps were fixed on revolving poles; and the expression "the board was on" or "the board was off" is retained amongst the engine-drivers on some of the older lines at the present time. The semaphore-arm, formerly so much used for telegraphic purposes, is now generally preferred as a railway signal. But its merits were not fully recognized until the "board" had passed through a great variety of forms, according to the ideas of the designers on different railway systems. The board was made round, square, triangular, oblong, fish-tailed, half-moon shape, long and thin, or short and stumpy, on different lines. In some cases two red discs, called spectacle-discs, were used for danger, and one green one for caution; and on the broad-gauge systems the disc was the all-right, while a cross-bar below it was the danger signal, and the arrow-head was used mainly as a time signal. So that the same indication was employed for danger on the narrow, and for all-right on the broad-gauge railways. Then, again, additions were made to these boards, discs, or cross-bars, by turning the ends up or down, or by excrescences at one side or the other, or by various methods, to indicate to the engine-drivers whether they applied to an up line or to a down line, to a main line or to a branch line. As the speed of the trains increased, and longer distances were required for stopping them, the signals were raised, and auxiliary or distant signals, worked by wires from a distance, came into use; and these, again, were sometimes distinguished by their forms from the home signals, when both were used; and in many cases distant signals were used without home signals. The home signals were worked by means of handles on the posts; the distant signals of levers on the ground, in what were considered convenient situations; and the points were worked by levers also on the ground, but scattered about, opposite to them, and frequently between the lines of rails. By degrees stations and junctions became more complicated, and the points and signals increased in number, and were at greater distances from one another. The signalmen sometimes had to leave their signal-levers, for the purpose of working points more or less distant from them, and occasionally at the opposite sides of lines of rails, which might be occupied by trains; and sometimes the points were worked by one man and the signals by another. But the mistakes, misunderstandings, and accidents which resulted from such conditions, —under which a signalman either himself omitted to work his points and signals in harmony, or signalled forward a train for one direction whilst a pointsman set the points for another direction,—led naturally to the concentration of the signal and point levers in or around the signal cabins; and, to afford a better view to the signalmen over passing trains, wagons in sidings, or other obstructions, the cabins were raised to a greater or less height above the ground, and placed in convenient situations, according to local circumstances. But even then, when the control was more conveniently placed in the hands of one man, there was still, as the levers in or near a cabin became more numerous, a liability to mistake, from the signalman pulling over a wrong lever; or the levers were fastened over by blocks of wood which the signalman forgot to remove; and, to prevent such mistakes, and serious accidents resulting from them, it became further necessary to interlock the levers with one another.

This important improvement was suggested, as being probably feasible, by Colonel Yolland, in a report dated January, 1856, on a collision which occurred on the 7th December, 1855, at the Bricklayers' Arms Junction on the North Kent Railway. It was patented by Mr. Saxby in 1856, and it made gradual progress between 1856 and 1860. By 1860 many further improve-

ments had been made by different persons, and the inspecting officers of the Board of Trade began to insist on the use of locking apparatus at the junctions of new branches with existing lines. The principle was also carried out in that year at the signal cabin at the entrance to the Victoria Station. In January, 1862, the author made the following, besides other recommendations, in reporting on a collision at the Walton Junction, near Warrington, on the main line of the London and North-Western Railway, on the first of that month:

"The points should be free to move when the signals are at "danger." The signalman should be unable to lower his signal for any train to pass until he has first set his points right for that train. After having lowered his signal for a train to pass, he should not be able so to turn his points in the wrong direction for that train as to cause a collision; and he should not be able to make any mistake in the working of his signals that can lead to a collision between any two trains. These improvements will necessarily lead to some alterations in the cabin itself, and the opportunities will be afforded in carrying them out of giving the signalman larger windows, that he may have a better view in each direction, and of providing him with telegraphic instruments and telegraphic communications, by means of which he may at least be warned of the approach of the trains upon the different lines which are under his control. This being an arduous and important post, and one at which considerable complication, and a very heavy traffic over two junctions are combined, I think it would be wise to employ three men to do the duty, and thus to reduce the periods of labor from twelve hours to eight for each man."

Taking a simple case of a double junction between a branch line and a main line, with the main line to the right, the branch line to the left, and the down line running north, there are several modes in which accidents may occur. A down main line, or a down branch line train may find the facing points set in the wrong direction, or partially open; or the signalman may split a train, as it is called, by shifting the points when it is passing through them. A branch line up train may run through a main line down train, or a main line down train may run through a branch line up train; or their engines may meet at the diamond crossing; or there may be collisions under different conditions between main line up and branch line up trains at the fouling point of the up lines; or the leading points may lie in the wrong direction on the approach of a train on either of those lines; or a train which is being shunted back from the up main to the up branch line may be met by a down main line train at the diamond crossing. By the application of locking and other apparatus it is possible to prevent nearly all of these accidents from occurring, in the ordinary way of working, in consequence of any mistake of the signalman. Conflict between signals, and conflict between points and signals, may alike be avoided; and a good combination of locking-bar and bolt may be made to insure that the facing-points are completely over before the proper signal is lowered, and may also prevent them from being moved during the passage of a train. It is, of course, impossible to provide against all the contingencies which may arise—such as, in certain cases, against the absolute neglect of engine-drivers to pay attention to the signals made to them; or such as a signalman, when two trains are running towards a junction at one time, setting his points and lowering his signals first for one of them, and then altering them and preparing for the second train, without allowing time for the first train to stop short of the junction. But provision may be made, and is made to some extent, even for the contingency of an engine-driver neglecting to obey signals. For instance, by making (in the example before referred to) the facing-points of the junction lead, as it is called, the trailing-points—that is to say, by so interlocking the levers that the former must be pulled over before the latter—it may be provided that any engine-driver approaching on the down line is necessarily turned along the branch down line, clear of the diamond crossing, when the points and signals are right for branch up-line trains to pass over that crossing, or when a train is being shunted back over it. There is, however, no means of providing against accidents from engine-drivers neglecting to obey signals on the branch up line, either when a main line down train has entered the facing-points, or when a main line up train is approaching the junction from the opposite direction.

In more complicated situations, when there are cross-over-roads between the

main lines or branch lines, or both, and through-crossings, and sidings connected at different points with the passenger lines, or where passenger lines are more numerous, and are connected at various points with goods lines and with one another, then the locking system becomes more complicated. But it is then, also, of still greater utility in securing the traffic from accidents, which become otherwise more likely to occur in consequence of mistakes on the part of signalmen. The same principles are applicable, but each case forms a problem in itself, to be carefully worked out according to its own circumstances; the objects being to give the signalman complete control over the traffic in every direction; to prevent him mechanically, as far as is possible, from making mistakes which may lead to accident; and to afford him the means of exhibiting a distinct indication to an engine-driver proceeding, or waiting to proceed, in any given direction. The control of the signalman is rendered more perfect by the addition of blind-sidings, so as to provide safety-points—where such are not in the laying out of the yard or lines otherwise available—to goods lines or sidings near their junctions with the passenger lines. These safety-points serve alike to prevent wagons from being blown out, or inadvertently run out or pushed out, and to prevent an engine-driver from proceeding against signals, and endangering the traffic on the passenger lines; but the levers of the safety-points require to be worked from the cabins, and to be properly interlocked with the other levers in the cabins.

Other devices, or provisions for enabling the signalmen better to perform their duties, may be mentioned; such as the system of slotting, as it has come to be termed, the connections of a signal, so that the arm of it may be raised to "danger" by a signalman in either of two neighboring cabins, but can only be lowered to "clear" by the joint action of the signalmen in both the cabins; the application of repeaters of various descriptions, either to inform the signalmen of the working of any signals which may be out of their sight, or to afford a more distinct indication, where such is required, to the engine-drivers; the means of information by telegraph as to when trains may be expected; clocks to furnish the correct time; register-books, in which to record the telegraph-signalling and passing of trains, so as to secure the regular performance of the duties, and to provide a check on the working of the signalman in any one cabin by the working of the signalmen in cabins on either side of it. But there are objections in the ordinary way to an overlap of the signals worked from one cabin by the signals worked from another cabin, as involving a liability to deceive the engine-drivers; and it is important to afford the means of all necessary communications between the signalmen, that they may not be working at cross purposes, and to deprive them of all excuse for making unauthorized signals on bells or block instruments to one another. Private signals or systems of inter-communication have frequently led to misunderstanding and accident. The selection and regular training of fit men for the performance of such duties; the employment of responsible inspectors for constant supervision, and the preservation of rigid discipline; the command of a sufficient number of relieving men, to take Sunday duty and to replace signalmen absent from sickness or otherwise; and the maintenance in high condition of the whole of the apparatus, are matters of obvious importance; but experience has shown that it is by no means unnecessary to refer to them.

When these desiderata are all properly worked out, and carried out in practice, great simplicity in working is obtained. Each signalman has control over his position, and is in a great measure prevented from making mistakes which may lead to accidents. The engine-drivers have in every case distinct indications to guide them, and are also, in many cases, prevented from causing accidents, even if they neglect to obey signals. The dangers of facing-points are for the most part obviated. Under such arrangements, engines and trains may be turned in and out and across one another with marvellous rapidity and facility, and in a way that would be impossible without the protection that they afford. The more numerous and complicated the lines, the sidings, and the crossings to be worked, the more indispensable does such apparatus become; and it is then, frequently, a means of considerable economy in the number of men employed, as well as a means of avoiding much sacrifice of life and limb to running pointsmen, yardmen, and shunters, whose services are to a great extent dispensed with. The simplicity in work-

ing thus obtained is not, however, apparent at first sight to the uninitiated, who see only an array of levers, and are not aware of the way in which they are named and numbered for the guidance of the signalman; each signal-lever bearing the number of any point or other lever that requires to be moved before it can be pulled over, and being also described as to its own particular purpose on a brass plate or otherwise. And it is not yet understood or appreciated in many cases by experienced railway officers who have not devoted much attention to this special branch of railway working. The comparative simplicity of the system will be best understood by an examination, and by watching the working, of any complicated stations or junctions at which it has not yet been applied; and it may to some extent be conceived by remembering what the confusion and complication in working would be if these levers were of all sorts, sizes, and shapes, scattered about in various situations, worked by different men, and independently of one another. An idea of the way in which confusion may be avoided will also be formed by comparison with the elementary principle of another system once in force, and much persisted in as being correct, on one of the great railways of this country. A signal-post was placed at a junction with one arm on it applicable to two conflicting lines of railway. It was an eminently simple arrangement in more than one sense. But it had the disadvantage that when two engine-drivers approached a junction from two directions at the same time, and when, seeing the one semaphore-arm lowered, or a hand-signal waved, each thought it was intended for him, they advanced together towards the junction, and then could not avoid in some cases running into each other. It was only after repeated collisions from this cause, and consequent remonstrances from the Board of Trade, that this arrangement, simple in construction, but which undoubtedly led to confusion in working, was at length abandoned. A simpler arrangement still, as far as construction is concerned, is a mere hand-flag, or hand-lamp, or the arm of a signalman; but, unfortunately, they are not well seen, and they are liable to be, as they have too often been, overlooked or wrongly interpreted, especially when signals require to be exhibited in several directions at one time; and thus it becomes necessary for true simplicity in working to employ what are sometimes complained of as complications, in the way of posts, levers, rods, cranks, arms, lamps, and glasses; and to provide a separate signal tor every purpose for which a signal is really required, to enable a distinct indication in every case to be exhibited by a signalman and received by an engine-driver.

(To be continued.)

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—April 15, 1874.—A stated meeting was held at 8 o'clock P. M.

Communications from Hon. William J. McAlpine, giving a record of "Experiments on Mixtures of Mortars and Concretes," and upon the power of earth to sustain foundations, were read and briefly discussed.

The death, on April 1st, of John B. Rogers, C. E., late of St. Louis, Mo., and Member of the Society, was announced; and Messrs. C. Shaler Smith, Thomas J. Whitman, and Walter Katté, were appointed a committee to present a fit memorial of the deceased.

A communication from Prof. Henry Morton, President of the Stevens Institute of Technology, relating to the founding of a "Testing Laboratory," for making complete and impartial tests of the characteristics, value and strength of materials used in the arts, was presented, and referred for consideration and report to a committee consisting of Messrs. Octave Chanute, Albert P. Boller, and Richard H. Buel.

A paper by Col. W. Milnor Roberts, in review of Revy's "Hydraulics of Great Rivers," was read, and the subject as referring to the improvement of the mouth of the Mississippi, discussed by Messrs. Chanute, Thurston, and others.

May 6, 1874.—A regular meeting was held at 1 o'clock P. M.

The vote on admission to membership was canvassed, and the following declared elected: Members, Charles E. Emery, M. E., of New York; John A. Judson, C. E., of Newport, R. I.; Otho E. Michaelis, Capt. Ordnance, U. S. A., of Pittsburgh, Pa.; Robert M. Newman, C. E., of New York, and Edward S. Philbrick, C. E., of Boston, Mass., and Junior, Russell H. Curtis, C. E., of New York. The death, on April 16th, of Jonathan Camp, Jr., C. E., late of Jersey City, N. J., and Member of the Society, was announced, and Messrs. Andrew J. Post, Charles Macdonald, and Arthur Speilmann, were appointed a committee to present a fit memorial of the deceased.

A paper by J. James R. Croes, C. E., on the "Flow of the West Branch of the Croton River," and referring to the relation between the flow and the rainfall, was read. Remarks on certain views contained in Revy's "Hydraulics of Great Rivers," and on the proposed improvements of the mouth of the Mississippi, were made by Col. W. Milnor Roberts and Gen. Theodore G. Ellis.

A report from the committee appointed February 18th, to consider the "Memorial of the American Metrological Society," was read, discussed and laid on the table; and one from the committee ap-

pointed February 4th, to which was referred a communication asking the Society to declare what should be the course of instruction in schools and colleges, for students of engineering, was read and adopted.

May 4, 1874.—A stated meeting of the Board of Direction was held at 2 o'clock P. M.

Proposals for admission to the Society were considered, and the President, Secretary, and Chairman of Committee on Finance were appointed a Committee on Applications, to whom all proposals for membership shall be referred for examination and report to the Board with such recommendations as the committee may deem proper.

The Treasurer presented his semi-annual report on the finances of the Society, which was accepted, and referred to the Committee on Finance.

The committee, appointed April 1st, to consider the expediency of a change in location of the rooms of the Society, presented a report which was accepted.

Messrs. John Bogart, W. Milnor Roberts, Charles Macdonald, Francis Collingwood, and Theodore Weston, were made a Committee on Rooms, to confer with kindred associations in New York, select chambers in a central location after the existing lease expires, and report to the Board. Members opposed to a change of place are requested to state their reasons therefor.

IRON AND STEEL INSTITUTE OF GREAT BRITAIN.—This Association has just concluded its spring meeting.

The leading topics presented were as follows:

The first paper read was by Mr. A. Smith, "On the Shaping and Finishing of Iron and other Metals by Solid Emery Wheels, and on Machinery Specially Designed for such Purposes." It was observed that the general rise in the price of labor and materials had caused the attention of manufacturers to be directed to the use of solid emery wheels as great labor-saving tools.

The "Berryman Feed-Water Heater" was described in the paper which was read by the gentleman whose name the apparatus bears. He explained that a feed-water heater is an important adjunct to engines and boilers where it is an object to economize fuel by utilizing the heat remaining in the exhaust steam after it leaves the engine.

The "Pernot Rotary Puddling Furnace" was described in a paper by Mr. Petin, of Paris, read by Mr. D. Forbes, the Foreign Secretary. It was stated that at first the process did not seem to promise much, but it is now unsurpassed by any in use in France.

The paper on the "Spathic Iron Ore Districts of Europe," by Mr. Charles Smith, of Barrow, which was read by the General Secretary, is of especial interest at the present time, because it is the raw material from which spiegeleisen is most conveniently produced, and spiegeleisen is an essential element in the Bessemer process for the manufacture of steel. Three or four years since it became a question whether it would be possible to utilize, for Bessemer steel purposes, the largely increasing make of suitable pig iron, in consequence of the small quantity of spiegeleisen brought into the market, most of which was derived from Rhenish Prussia. It was, therefore, most important to know if the existing production could be increased, and if it were possible to obtain additional supplies from fresh districts.

"The Manufacture and Use of Spiegeleisen" was the subject of the next paper, by George J. Snelus, who stated that spiegeleisen was of but small value formerly, but in course of time its use in the Bessemer process brought it into prominence, and raised its value. It was first made and used at the Ebbw Vale Works, and in time, as the market for it increased, its manufacture extended to other parts, and it had now become an important and an established industry.

"The Condition in which Silicon exists in Pig-Iron" was then discussed, in a paper by Mr. E. Handfield Morton, who said he had been induced to make a few experiments by noticing that silica was obtained in an insoluble residue when pig-iron, containing a large quantity of silicon, was dissolved by diluting sulphuric acid *in vacuo*, instead of silicon. This fact pointed out that the theory of silicon being intimately mixed with pig-iron was untenable.

The last paper read was that on "Coupling Power for Rolling Mills," by Messrs. F. N. Varley and Furness, who described a means for controlling or reversing mills which received their power from a continuously and uniformly driven shaft, where the fly-wheel picked up the accumulated momentum, and the shaft to all practical purposes might be considered to be driven at a uniform rate. A means for quickly arresting a rotation body might be obtained by altering the direction of the force so as to avoid a sudden shock. The accomplishment of this idea was explained by diagrams, and it was shown that in the case of any sudden strain on the wheel the shaft and attachments would not receive the shock, and that the force of the blow would be spread over a period of time sufficient to destroy its intensity.

IRON AND STEEL NOTES.

STATISTICS OF THE IRON AND METAL TRADES.—In the introduction to the new edition of Messrs. Kelly & Co.'s "Iron and Metal Trades Directory," there have been collected a number of figures indicating impressively the vast extent and importance of these industries, which furnish employment directly to nearly a million and a half of our population.

Turning to the metal with which we ourselves are more particularly identified, we find that the total quantity of iron ore raised in 1872 from 266 mines was 15,584,857 tons, and, adding the foreign ores imported, 16,539,889 tons of iron ore were smelted in Great Britain. In the same year there were made in England, 4,594,614 tons of iron; in Wales, 1,057,315; and in Scotland, 1,090,000; the number of furnaces employed in each country being respectively 450, 122, and 130; 276 mills and forges were also returned as at work, having 7,133 puddling furnaces and 1,015 rolling mills, together with nineteen works employing 91 Bessemer converters. Besides the iron worked up in our own manufactures, nearly three millions of tons, valued at about £38,000,000, were exported in 1872. From 1850 to 1870, the declared value of British produce and manufactures, mineral and

metallic, rose from about fourteen millions sterling to forty-three and a half, the iron and steel in the last-named year being valued at £21,675,218, or four times what it was twenty years previously; machinery and mill-work to nearly six millions; and hardware and cutlery to nearly four. The value of coals, coke, and patent fuel exported in the same period increased from £1,284,224 to £5,638,371. In 1873, iron had risen still farther to £37,779,586; coal, etc., to £13,205,618; hardware and cutlery, to close upon five millions: the metallic exports for that year reaching a grand total of £75,107,840, nearly thirty-two millions sterling over those of 1870. Tin, terne, and black plates form a comparatively large item in our metallic exports, amounting in 1873 to 120,468 tons, valued at £3,952,841. The extent and importance of our coal mines may be judged of from the following figures: The number of collieries in the United Kingdom is upwards of 3,000, from which, in 1872, there were raised 123,497,316 tons, valued at £46,311,143. Of this there was used in making pig-iron, 17,211,729 tons; in the metallurgies, 371,605; exported to foreign countries, 13,187,494 tons. In the following year about 15,000,000 tons were shipped abroad, their declared value being £13,205,618. Of the workers in metal in the United Kingdom 376,783 are miners; 174,704 workers, etc., on arms; 779,838 workers and dealers in minerals and metals; and 16,742 machine and tool-makers.

Much of the manufactured iron retained in the country consists of machinery. The estimate for 1870, which is believed to be considerably understated, was that there were then in the United Kingdom 6,708 textile factories, running over forty-five million spindles and nearly six hundred thousand power-looms, giving employment to over a million of the population—nearly double the number employed in 1855.

The railways also take up a very considerable amount of home-made iron, and both steel and iron rails and engines are largely exported to the colonies and foreign countries. The increase in the mileage of railways in the United Kingdom between 1850 and 1873 was 9,000 miles—well on to double—and the number of locomotives, 9,500. In India and the Colonies there are upwards of 12,300 miles open. A large quantity of iron and other metallic material is used in telegraph construction. There are 3,374 miles of submerged cable wire in the United Kingdom, 83,408 miles of public telegraph wire, and 4,311 miles of private wire. There are in India and the British Colonies upwards of 65,000 miles of wire fixed, and much of the submarine cable in all parts of the world is manufactured in England. There are also over 60 wire-rope manufactories in the kingdom, this fabric being, besides its employment in telegraphy, more and more extensively used as a substitute for vegetable fibre.

Another new and increasing department of iron-work is the manufacture of agricultural implements. In England and Wales alone there are 3,617 agricultural implement makers, and from 30,000 to 40,000 steam-engines employed in farming operations.

The iron and wooden steamships which plough the main almost rival in number the sea-birds which float on or fly over it. According to the latest official returns, there were registered as belonging to the United Kingdom in 1873, 3,852 iron steam-vessels, of 1,711,767 aggregate tonnage. In the same year no fewer than 63,000 British steam-vessels of both kinds, measuring 50,388,055 tons, entered with cargoes at ports in the United Kingdom from foreign countries and the coasting trade—a marvellous increase from the 104,680 tons in 1850.

Phosphorus in Bessemer Pig.—Mr. Platt asks in the "Engineering and Mining Journal" the amounts of phosphorus and other ingredients allowable in Bessemer pig. The amount of each depends, to some extent, on the amounts of the others. Either carbon, or some metal, such as manganese or silicon, is necessary to give body to steel, and these substances may replace one another. If the steel has 0.15 of phosphorus, and an average amount of other ingredients, it will be made brittle by 0.30 of carbon. But if it contains but 0.05 of phosphorus, other things being equal, it will not be made brittle by 0.75 of carbon. Phosphorus and silicon, above, say 0.10 per cent., produce a decided tendency to cold-shortness. Manganese, up to 0.75, does not, of itself, appear to impair toughness, although so large a percentage cannot be allowed in rail steel containing 0.10 of phosphorus, 0.10 of silicon, and 0.30 of carbon. I am not attempting to give absolute formulæ, nor even a general rule for the synthesis of steel. We have too few analyses of mechanically tested specimens to warrant any such close conclusions. I am simply illustrating the tendency of these outside substances to replace one another as body-givers to steel.

Therefore, equally good Bessemer pig-irons may vary considerably; if they are rich in phosphorus they must be poor in other cold-shortening. If they are rich in copper they must be poor in sulphur and other red-shortening. The average percentage of phosphorus in twenty-seven Lake Superior pig-irons, the analyses of which are before me, is 0.13. Most of these are suitable for Bessemerising, and I think Lake Superior Bessemer pig averages about 0.12, but it is quite pure otherwise, and admits of being well-blown, *i. e.*, thoroughly decarburized, so that the resulting steel is as tough as any in the market. As much phosphorus as this, in the English Cumberland irons, and in some American irons, would tend to produce brittleness. The amount of phosphorus allowable also depends upon the amount of carbon restored by the recarburizer. Of common spiegeleisen, having 10 per cent. of manganese and 5 per cent. of carbon, some 8 per cent. must be put into the blown metal, in order to introduce manganese enough to cure red-shortness, and a good deal of carbon is thus necessarily introduced. Eight per cent. of spiegel added to a well-blown iron will give 0.30 to 0.40 of carbon in the steel. But if a ferro-manganese having, say 60 or 70 per cent. of manganese, and only 2 or 3 per cent. of carbon, is employed, so little of it is needed to furnish the requisite manganese that the accompanying addition of carbon is very slight; hence more phosphorus may be present. This is the basis of the Tessié du Motay process in use at Terrenoire, France. Silicon in Bessemer pig averages about 2½ per cent. As much as this is needed to produce sufficient heat. Some mineral coal pigs contain 4 per cent. and over; some charcoal pigs have but ¾ per cent. of silicon.

The *mixture* used should have 2 to 3 per cent. Sulphur in Lake Superior Bessemer pig rarely runs above 0.02; in Missouri pig, rarely above 0.01. Sulphur in English Bessemer pig averages about 0.10. Two or three per cent. of manganese would be valuable as a purifier, though too much would make the blowing difficult, and it would not take the place of the spiegel. Of other metals there is not likely to be enough to do much good or harm, in such American ores as have been developed.—A. L. HOLLEY.

FRENCH IRON STATISTICS FOR 1873. The total make of pig iron in France in 1873 was 1,381,000 tons, being only 17,000 tons less than that of 1869, the largest that was ever reached having been 1,398,000. Compared with 1872, the increase has not been less than 200,695 tons. The total output of manufactured iron in 1873 amounted to 906,745 tons as against 883,079 tons in 1872, showing an increase of 23,666 tons. There is a falling off, however, of 126,000 tons compared with the extraordinary make of 1869. The total production of steel during the year reached 167,677 tons against 138,552 tons in 1872, or an increase of 29,125 tons. Since 1867 the steel manufacture in France has increased tenfold, and the upward movement is likely to continue. The sum total of iron and steel rails which the sundry railway companies ordered from the home works during 1873 is 188,815 tons, of which 124,717 tons were of iron and 64,098 tons of steel. The Paris-Lyon-Mediterranean railway alone consumed during the year 32,500 tons of steel rails; the Nord, 14,625 tons; the West, 9,871 tons. Compared with 1872, the consumption of iron rails increased 20,750 tons, and that of steel rails 11,903 tons. Adding to the above figures 8,544 tons of iron rails and 2,000 tons of steel rails imported during the year, we find for all the French railways together a consumption of 133,261 tons of iron rails, and 66,098 tons of steel rails, or a grand total of 199,359 tons.—*Bulletin du Comité des Forges de France.*

RAILWAY NOTES.

GRANTHAM'S STEAM CAR FOR TRAMWAYS.—An experimental trial of a steam tramway car, which appears likely to satisfy all the material requirements of such a conveyance, was made recently in a field near the West Brompton Station of the District Railway. The inventor, Mr. John Grantham, C. E., besides his special qualifications, has had much experience in such matters both abroad and at home. Among other things, he personally laid out the Copenhagen Tramway, a work very difficult of execution. Since small steam-engines have been brought into general use, various improvements have been introduced, and these and others of his own suggestion Mr. Grantham has combined and applied to the use of the modern tramway system. In carrying out the practical details of a tram car also, it is to be observed that a short wheel base is required to enable it freely to pass the curves, while the car itself must be of great length to accommodate a sufficient number of passengers. This involves the necessity of placing the weight of the machinery in the centre. Steam cars having the machinery at the ends have been tried, but the arrangement is destructive of all the requirements above described. A long wheel base, however, has its advantages in keeping the car steady. To accomplish this, and still to ease the motion at the sharp curves, Mr. Grantham has adopted the bogie system, now prevalent on many railways. This arrangement has also important advantages of another kind. By a simple addition to the bogie frame, he has been able to introduce a plan for guiding the car, so that no movable switches are required at the sidings—a point of great importance on tramways. It also gives the power to leave the rails when an obstruction occurs, or to get on them again when the car is accidentally thrown off.

The car used at the trial, on Saturday, weighed some four or five tons, and resembled in shape those which it is intended to supersede. The engines, which are almost totally hidden from view when the car is in motion, are placed in the middle of the vehicle, on either side. The cylinders are 4 inches in diameter, with a 10-inch stroke, worked direct on the crank axle. Fuel is now supplied by hand, but we were informed that future cars will be furnished with an automatic feeder. It is calculated that the quantity of coal which would be consumed in a twelve-hours' running would be about 5 cwt. The car can be worked from either end, the driver having simply to shift the lever from one end to the other. Several trips at various speeds, from seven to about fifteen miles an hour, were made along a line laid on the side of a grass field, and extending for about a quarter of a mile. Nothwithstanding the unfavorable nature of the ground, the runs were made with almost perfect smoothness and steadiness. There was no noise, save the rattle of the wheels, and neither smoke nor steam was visible. Inside there was neither heat nor smell from the machinery. While running at seven miles an hour, the car was brought to a standstill, by means of a foot-brake, at about half its own length. It is intended to use for this purpose a light hydraulic brake, which will be applied to the axles, and a guard or cow-catcher will be attached to each end of the cars.

One of the most important features in connection with Mr. Grantham's invention is that whereby the driver has such a command over the forewheel that on approaching a junction, instead of having, as in the case of horses, to pull the horses over, or to be dependent on a switch boy, he can, by the simple application of a lever, divert the course of the car. Future cars will have the advantage of that experience which has been the outcome of the construction of the present one. Bells which keep constantly ringing by the aid of machinery when the car is in motion, will also be placed at each end of the car. The small quantity of steam now occasionally visible when the car is running continuously will also, we understand, be considerably diminished.

Mr. Grantham contends that it is a narrow view to suppose that improved tramways will interfere with railways. It may fairly be expected that they will become feeders rather than rivals. In some localities their interests may clash, but the reverse will be the rule. Extended as is the net of the railways that now intersect this country, many small towns and villages are suffering for want of them, and are being left behind in the rapidly-increasing facilities which large towns,

and even small ones, which happen to be in the railway routes, are receiving. The costly railway and its heavy engines and plant require a traffic which few small towns or villages can support, while the horse omnibus and the carrier's cart, over rough roads, are the only means of communication for the people. A London tramway car at present requires ten to twelve horses, and as each horse costs about £60 per annum, the total expense of horses alone is from £600 to £700, independent of the wages of the driver, conductor, and of the car itself. By using steam-engines as substitutes for horses, the experiments with the present car show the following results :—To work the car for fourteen hours requires 5 cwt. of coke and coal mixed, which, at the average cost of fuel in various places, will amount to 5s. to 7s. 6d. a day ; add to this the extra wages to the engine-driver, the wear and tear, and sundries, about equal to the cost of fuel, leaving an annual expenditure of about £250, or a saving of about £400 for each car.—*Iron.*

ENGINEERING STRUCTURES.

THE EAST RIVER BRIDGE. This important structure which has remained as the workmen left it in December last, is again to be pushed forward with activity. The New York tower is 123, and the Brooklyn tower 222 ft. above high water. The latter will doubtless be completed this year. Work on the Brooklyn anchorage will also be at once resumed.

THE WILLIAMSBURG DAM. *Report of the Committee Appointed by the Society to Investigate the Causes of its Failure—Chairman of Committee, James B. Francis, of Lowell, Mass.* The dam is between 500 and 600 ft. long, and about 43 ft. high at the highest point near the centre, diminishing to nothing at the ends, forming, when filled, a reservoir in the valley above it of an area of 111 acres, with an average depth of about 20 ft. At the time of the failure the water was about 4 ft. below the top of the embankment, not an unusual height at this season, and within a few months it has been at least a foot higher. The failure took place between 7 and 8 o'clock on the morning of May 16, when probably ¾ of the contents of the reservoir escaped in about 20 minutes, or at the rate of about 60 cubic ft. per second, destroying in its course through the steep and narrow valley below 143 lives, and property to the amount of more than $1,000,000. The dam consists of an earthen embankment with a longitudinal wall of stone and cement through its centre, a waste-way 33 ft. wide in the natural ground at one end of the embankment, and a 16 in. pipe through the embankment and wall at the lowest point for the discharge of water as wanted for use at the mills below.

Two or three plans for a dam at this point were prepared and rejected by the Company on the ground of their cost; one of them by the late Mr. Stewart S. Chase, a member of the Society. The plan adopted, or rather the specifications, for it does not appear that any plan was drawn, were prepared by Mr. Lucius Fenn, civil engineer, now of New Britain, Conn., who, according to the evidence reported to have been given by him at the Coroner's inquest, claims to have written them under the direction of the Direction.

The Main Reliance on the Wall.—On a personal examination of the site and remains of the dam, we find that the bottom is a very compact hard-pan overlaid by about two feet of coarse gravel and a few inches of soil. The hard-pan appears to be impervious to water, or as nearly so as any soil can well be, and at the breach is but slightly washed, except near the discharge pipe, where there is a gully several feet in depth, which may, however, be due in part to the former action of the brook. The gravel overlying the hard-pan is washed and porous. A small spring is now to be seen coming out from under the remains of the embankment above the centre wall, which is evidently superficial, and from the gravel. The embankment is formed of gravel similar to that above described, but containing a little loam. It was taken from the side of the hill just above the dam. It has scarcely anything binding in its character, and is not capable of being made into a puddle which would stop the percolation of water. From the character of the bottom, and the material available for the embankment, it is obvious that the main reliance for retaining the water must be in the cement wall and the complete union of its base with the hard-pan ; the main office of the embankment being to support and protect the wall. By the specifications nothing more was required than "trenches 3 ft. deep, or of sufficient depth to give a firm, hard and secure bottom for the masonry to rest upon, and which will not allow the masonry to settle ;" the intention evidently being only to secure a foundation sufficient to prevent settling, as if for a building or bridge abutment, totally ignoring the vital function of the cement wall by not adopting means to prevent the passage of water under it.

No Security even if built according to Specifications.—It was undoubtedly expected that the embankment would prevent the water in the reservoir from reaching the base of the wall, and to make this sure the specifications provide "the earth to be placed in thin layers, wet and tamped, or beaten with a maul for a distance of 5 ft. each side of the entire wall." Supposing this to have been done as perfectly as possible with the material, what security could it give against a pressure of 40 ft. head of water?

The remainder of the embankment on the up-stream side, being built in layers of 5 ft. in thickness of this porous material, could evidently not be depended on to supply the deficiency. The water in the reservoir, we are informed, is always clear, as might be inferred from the character of the water-shed, which, as far as observed, consists of steep, rocky pasture and woodland. There would consequently be very little deposit of sediment on the embankment, which might otherwise in time have rendered it water-tight.

The specifications are also defective in providing for slopes of only 1½ to 1. They should be at least 2 to 1 on the outside, and 2½ to 1 on the inside. Another defect is in providing for a height of the embankment only 2 ft. above the top of the centre wall. The height should be sufficient to protect the wall completely from frost, which in this climate requires 5 ft. of earth at least. If the earth becomes frozen to the wall it is liable to

heave or fracture it. We give no particular description of the discharge pipe and waste-way, as the failure in the dam appears to be wholly unconnected with them.

In the construction of the work by the contractors it appears that there was no sufficient inspection, so peculiarly important in a work of this description, and during great part of the time none at all, except by the Directors of the Company, or their Building Committee during their occasional visits. The remains of the dam indicate defects of workmanship of the grossest character. The bottom of the wall does not in all cases even rest upon the hard-pan. It was in evidence at the inquest that the wall was laid up dry, and grouted 5 ft. high at a time. The grouting has not completely filled the cavities, and the quality of the mortar is, some of it, very bad, as might be expected from this mode of building. The soil and porous gravel were only partially removed from the base of the embankment for 30 ft. on each side of the centre wall, as required by the specifications.

The Work not to be Justified on Engineering Principles.—It is probably not possible to ascertain with certainty the immediate cause of the failure, but from the evidence obtained we can come to no other conclusion than that the water found its way under the wall at a point about 100 ft. from the discharge pipe, causing a slip in the embankment on the down stream side of the centre wall, which, being then unsupported, yielded to the pressure on the upper side, and, falling over, made a breach, which was rapidly enlarged by the washing away of the embankment and the fall of the other parts of the wall.

It may be asked, if this was the immediate cause, why did it not happen before when the reservoir was at a higher level? The answer, we think, would be, that there has been a gradual working out of the gravel under and near the wall, and loose places or cavities formed, which, when they had attained a certain development, would suddenly lead to their failure.

The Committee understand that the principal object of their appointment to report on this matter was to study it as an engineering work, it being well understood that usually more is to be learned from one failure than many successes; but it is obvious that this cannot be called an engineering work. Its engineer, or person calling himself such, can be held responsible for either its design or execution. According to the evidence reported, it must be considered as the work of non-professional persons. This being the case, the Committee do not think it devolves upon them or on the Society to criticise its design or execution. The causes of a failure attended with such disastrous consequences cannot fail to be interesting to the members of the Society, and we have endeavored to point them out.

In connection with this report, W. E. Worthen of New York exhibited a model of the broken dam, and explained in brief terms the manner in which the break was first discovered, and the subsequent sliding away of the wall. He said that it was far from being his opinion that persons could build reservoirs by intuition. A thorough knowledge of the power of water as well as the strength of masonry was required, and this necessitated study. The employment of men who did not understand water was not judicious, to say the very least; and those who employed them have found to their cost that it was an unwise economy.

ORDNANCE AND NAVAL.

PRESERVATION OF THE IRONWORK OF THE HULLS OF COMPOSITE SHIPS.—The Lords Commissioners of the Admiralty have issued a circular, No. 31 S, specifying the duties of dockyard officers and of officers in commissioned ships of composite build, with reference to the preservation of their iron frames, etc. It directs dockyard officers to see that (*a*) bilge pipes are not of copper, brass, or lead, except those belonging to the engines, which are necessarily of brass or copper, and that such are to be painted and clothed with canvas; that (*b*) parts necessarily inaccessible are to be specially pointed out to the officers of the ship; (*c*) the frames to the turn of the bilge covered with cement or suitable composition, but painted elsewhere; (*d*) the cement to be examined wherever accessible when the ship is in dockyard hands; (*e*) and a thorough examination every three years; (*f*) including in this all dockyard craft or other vessels belonging to the port. It directs the officers of the reserve and of commissioned ships that (*a*) the chief engineer and carpenter are to examine the ironwork every six months, and make a joint report; (*b*) any decay or want of cement or paint to be made good, (*c*) and the Secretary of the Admiralty informed of what was seen and done. Examinations are to be thorough (*d*) every three years, and (*e*) a special report to be made thereon, if not at a royal dockyard. This circular practically provides for composite ships what circulars 28 of 1872, and 22 of 1873, provided for iron ships and iron ships wood-cased.—*Engineering.*

BOOK NOTICES.

THE UNIVERSAL REVIEW OF MINING, METALLURGY, PUBLIC WORKS, SCIENCE, AND THE INDUSTRIAL ARTS. Being the English edition of Revue Universelle des Mines, de la Metallurgie, etc. London: W. Richards Hutchings, 5 Bouverie street.

The first number of this work has now made its appearance, and in every respect fully justifies the high anticipations that had been formed of it. The contributors are all well known for their special acquirements in matters relating to mining, metallurgy, and cognate matters. They are associated with the central and other celebrated schools of Paris, and with the engineering branches of the chief industries of Liege, Charleroi, etc., in Belgium. We have read each article not only with profit but pleasure, and to those of our readers who desire scientific articles upon the subjects named above, which are free as possible from scientific technicalities, we recommend this work. We give below the contents for the number before us: I. Notes on Coke Ovens. H. Steel Rails, as used by the principal Railway Companies in France. III. Applied Ceemistry, as illustrated in the Vienna Exhibition, 1873. IV. The International Congress on Patents. V. On the Conditions of the Manufacture of Extra-Silicious Pig Iron in the Blast Furnace. VI. Notes on Work

Performed by Compressed Air. VII. Boring Machines, Worked by Compressed Air. VIII. The Economy of Fuel. IX. Notes on Experiments made by M. Lhoest, at Maestricht. X. Notes on Manufacture of Caoutchouc. XI. The Manufacture of Wrought and Cast Iron by Charcoal, in L'Entre Sambre-et-Meuse. XII. The Appendix ("Bulletin"). (1) On the Use of Steel Rails in Russia. (2) Lightning Conductors. (3) Tests of Steel. (4) Tariff of Import Duties to the Zollverein of Iron and Castings.—*American Manufacturer.*

A Conversation on Mines, etc., between a Father and Son. By Wm. Hopton. For sale by D. Van Nostrand. Price $1.50.

This is the fifth edition of this little book.

It affords, in a familiar style, an insight into the details of practical mining. The rudiments of mining surveying are elucidated in this much better than in more pretentious works.

Neither the typography nor the cuts are very attractive in appearance, but the value of the whole matter of the book to the young learner is unquestionable.

On the Origin and Metamorphoses of Insects. By Sir John Lubbock, Bart. London: For ale by D. Van Nostrand. Price $1.50.

This book seems of too small dimensions to treat adequately of so extensive a subject. The distinguished author, however, knows how to say much in a few words. A great number of cuts is always needed to illustrate such a topic as this, and the want is abundantly supplied; the separate figures average two to each page of descriptive text.

The subjects to which the separate chapters are devoted are:

I.—The Classification of Insects.

II.—The Influence of External Conditions on the Form and Structure of Larvæ.

III.—The Nature of Metamorphoses.

IV.—The Origin of Metamorphoses.

V.—The Origin of Insects.

The Science of Embankments. Van Nostrand, the publisher of the engineering profession, sends us one of his "Science Series," a little brochure on the "Designing and Construction of Storage Reservoirs," by Arthur Jacob, a Royal Engineer of considerable experience in India. In the East, reservoirs, or tanks as they are there called, are very common for the storage of water for irrigation; and now during the famine, when it is necessary to employ the people to keep them from starving, most of the work is directed to the construction of new tanks. The ancient reservoirs of the East put our modern civilization quite to shame, some of those in India having embankments 20 and 30 miles in length. Some of these have fallen into disuse on account of the expense of keeping them in repair; but there is one in Ceylon 15 miles long, with a wall of solid and matched masonry, buttressed with earth to a breadth of 100 ft. at the base and 40 ft. at the top. There is no sham about that, and because it was built by impressed and unpaid labor. Mr. Jacob's essay is written for the latitude of England, but does not seem to be made useless for us by the distance of his experiences. Earth and water are the same at the antipodes as here. First, as to the strain or pressure of water, he gives a rule which may interest the inexpert. The weight of water against a perpendicular wall is equal to the product of the area of a perpendicular section of the water, multiplied by the depth of the centre of gravity of the wall below the surface and by the weight of a unit of water. A perpendicular dam, 10 ft. high, and sustaining 10 ft. of water, sustains for every foot in length 3,125 lbs., this being the product of 10 sq. ft., the area of water, by 5 ft., the distance from the top to the centre of gravity of the wall, by 62½, the weight of a cubic foot of water.

But Mr. Jacob cautiously observes that "the principles that direct the design of embankments to retain water are not those that apply to calculations of the forces to be resisted or the means to overcome them, any more than breakwaters and harbor walls can be designed on mathematical principles." We come at once upon one principle, however, which was violated at Williamsburg. According to the statement of one of the proprietors, this reservoir was built with a slope on the inside of 45 deg., the slope at which earth out of water is stable. But in water a much greater slope is required, and as soon as this oversight was discovered, an attempt was made to remedy the difficulty by dumping in earth and stones. Mr. Jacob states that "earth, when subjected to the action of water, almost invariably loses a certain amount of its stability, and in most of the best existing examples the inside slope of the bank is either 3 to 1 or 2½ to 1"; that is, 3 ft. slope to 1 ft. perpendicular height, etc. He prescribes for the outside slope, 2 to 1 or 3 to 1. "The impermeability of earth is a matter that cannot be relied upon." He thus describes the best English embankments:—

"The practice adopted in the best English embankments has been to carry up the earthwork in layers of 2 or 3 ft. in thickness, and, at the same time, to construct in the centre of the bank a wall of well-puddled clay, the foundation of which is carried down for whatever depth may be necessary in order to reach an impermeable bed of earth or rock. It is not in all situations possible to procure earth exactly suitable and in sufficient quantity for the construction of an embankment, and consequently it is advisable to dispose the best part of the material—that is, the most retentive of water—in juxtaposition to the puddle-wall. Earth should not be removed from the bed of the reservoir, as a natural basin of clay may thus be irretrievably broken through. In specifying for the dimensions of the puddle-wall, a sound rule for adoption is that it shall have *a thickness of* 10 *ft.* at the top water-line, and increase in thickness to the surface of the ground at the rate of 1 in. on either side for every foot downward."

The author recurs to the Sheffield disaster in 1864, and to the irreconcilable differences of engineers regarding that work. In that case the bank was 95 ft. high, with a top width of 12 ft., and slopes of 2½ to 1. The puddle-wall was 16 ft. in width at the ground-line, and tapered to 4 ft. at the top. Mr. Jacob says, that the fault of this dam was the too great reliance upon the masonry, the earth being put in loosely. The presumption that 25,000 ft. in area of masonry was to be constructed without a flaw he regards as

reckless. He agrees with Stewart Chase and Mr' Briggs, that the puddle is merely an accessory to arrest the damage of vermin burrowing in the earth, or the dissolving of soft spots in the earth itself. He finally places the only safety where the "Republican" has already placed it—in an impermeable lining of the reservoir embankment. "The most desirable as well as the most usual practice," he says, "is to pitch the whole of the inner face of an embankment with stone, carefully laid by hand. Neglect of this precaution has led to the destruction of many embankments, in other respects securely constructed."—*Springfield Republican.*

MODERN ENGINEERING.—A Lecture delivered before the American Institute. By WM. J. MCALPINE. New York: D. Van Nostrand. Price $..50.

The above lecture has been widely published already in the scientific journals. It was delivered in December, 1868, and the edition published at that time has gradually become exhausted; hence this second edition. The relation of old science to the new is pleasantly portrayed, and the statistical facts, which are compactly presented, give substantial value to the lecture, and render it worth preserving.

The attempt to entertain a popular audience, and at the same time present truths that engineers could listen to with pleasure and profit, proved eminently successful.

THE CONSTRUCTION OF MILL-DAMS. Springfield, O.: For sale by D. Van Nostrand. Price $2.50.

This work consists largely of a series of articles published originally in "Leffel's Milling and Mechanical News." The degree of interest manifested in the original articles satisfied the publishers that a volume comprising the best obtainable information on the Structure of Dams would meet a public want.

The book is not put forward to advocate a theory, nor, indeed, to sound the praises of any particular engineers or builders, but to briefly and plainly describe the details of established works.

The text is illustrated by many cuts, which, without being of excellent quality, are sufficiently good for the purpose

THE DISTRIBUTION OF RAIN OVER THE BRITISH ISLES DURING THE YEAR 1872. Compiled by G. J. SYMONS, F. R. B. S. London: Edward Stanford. For sale by Van Nostrand. $2.50.

Meteorological reports never afford very lively reading, and but few readers consider them profitable. Such statistics have an undoubted value, however, and to quite a variety of inquirers.

Hydraulic engineers and agriculturists, who regard the drainage and storage of water with interest, look upon the records of past years with a practical eye, while the physicist, seeking for the development of a law, scans the figures to see if a cycle can be detected in the seeming irregularities.

The present report abounds in maps, and affords excellent suggestions to observers, which apply to all localities.

THE PHYSIOLOGY OF THE CIRCULATION IN PLANTS, IN THE LOWER ANIMALS, AND IN MAN. By J BELL PETTIGREW, F. R. S. London: For sale by D. Van Nostrand. Price $4.00.

The author says of his labor in preparing this volume: "I have endeavored to give a comprehensive account of the circulation, and the apparatus by which it is effected in Plants, in the Lower Animals, and in Man. I have discussed the subject in its totality, in the hope that those parts of the circulation which appeared obscure in the higher animals might be simplified by comparing them with similar parts in the lower animals and in plants. This mode of treatment involves details, but these, I trust, will be found also to add additional interest. I have introduced a large number of drawings in place of the diagrams originally employed in illustrating the course in order, in some measure, to efface the traces of lecturing." One hundred and fifty wood engravings illustrate the text.

PRINCIPLES OF MECHANICS. By T. M. GOODEVE, M. A. Lecture on Applied Mechanics at the Royal School of Mines. London. For sale by D. Van Nostrand. Price $1.50.

In this work the author has given an outline of the introductory part of his lectures at the School of Mines, in which he presents a comprehensive view of the principles of mechanics, aiming above all to show the relation of the theory of heat to that science. The contents include not only an exposition of the fundamental principles of mechanics, more or less fully discussed, but also chapters on the mechanical powers, the equilibrium and pressure of fluids and gases, pumps, hydraulic presses and gauges, on girder-beams and bridges, and on some important mechanical inventions.

SANITARY ARRANGEMENTS FOR DWELLINGS. By W. EASSIE, C. E. London. For sale by D. Van Nostrand. Price $2 75.

Mr. Eassie, who is familiar with the questions here raised and discussed, has produced a book which must prove equally useful to officers of health, constructors of houses, and householders. The principal and most usual sanitary defects in dwelling-houses and public institutions in respect to drainage, water supply, ventilation, warming, and lighting, are described, and the most simple and effective means of preventing or remedying such defects set forth. Several paragraphs which had been noted for extract have been kept out by want of space; but the book, which is not an expensive one, will amply repay perusal.

HYDROSTATICS AND PNEUMATICS. By DIONYSIUS LARDNER. Revised and rewritten by BENJAMIN LOEWY, F. R. A. S. London: Lockwood & Co. For sale by Van Nostrand. Price $2.50.

The best elucidation of the principles of Hydrostatics ever afforded to the learner in Physics has been that of Lardner's Natural Philosophy. This treatise has been detached from the main work before and published as a separate volume. We have one before us even now bearing date of 1831, and put up in elegant binding. No work has been so widely recommended to students in this

department of Physics, and none has done such good service.

The revision needed to adapt it to present requirements, was not extensive; but it has been judiciously performed, and we have again an invaluable aid to students and teachers.

THE PRACTICAL ASSAYER. By OLIVER NORTH. London: Chatto & Windus. For sale by Van Nostrand. Price $3.75.

This book affords clear and concise directions to the amateur Assayer, and such as he can follow with success even though he has not acquired skill in the general processes of analytical chemistry. Direct and inexpensive processes are described for assaying Copper, Silver, Gold, Tin, Lead, Iron, Zinc, Mercury, Manganese, Bismuth, Nickel, Cobalt, Sulphur, Arsenic, Sodic Nitrate, and Guano. A few illustrations only are afforded, but perhaps as many as are needed.

A TREATISE ON THE ANALYTIC GEOMETRY OF THREE DIMENSIONS. By GEORGE SALMON, D. D., F. R. S. Dublin: Hodges, Foster & Co. For sale by Van Nostrand. Price $7.00.

A new edition of this excellent work will be gladly received by students of the higher analysis. The present work is just out of the author's hands, the preface bearing date March, 1874. Some important additions by Prof. Cazley are acknowledged by the author. The Appendix, relating to Quaternions, which appeared in the former edition, is omitted in the present one, as the recent treatises on the subject have rendered such an addition to this work unnecessary.

The widely increasing use of Salmon's "Analytical Geometry of Two Dimensions" is the best possible testimony to the value of the mathematical works of this now well-known writer.

EXTINCT VERTEBRATE FAUNA OF THE UNITED STATES. Contributions to the Extinct Vertebrate Fauna of the Western Territories of the United States. By Prof. JOSEPH LEIDY. Government Printing Office, Washington. For sale by Van Nostrand. Price $3.50.

This important volume is the first of five which are to form the "Report of the United States Geological Survey," and it will be supplemented by a memoir, embracing the same subjects, by Prof. Cope.

The large field for paleontological work recently opened up in the Western Territory of the United States has been as fruitful in the introduction of new and unexpected forms of extinct vertebrate life, as that so ably worked out by Cuvier, the Paris basin. By the establishment of a military station at Fort Bridger, opportunities have been afforded to geologists, which the offensive attitude of the Indian tribes had previously deferred, rendering inaccessible a district, the richness of whose past fauna must have been as remarkable as is its present desolation.

Fort Bridger is a military post about 100 miles E. N. E. of Great Salt Lake City, in the southwest corner of the Wyoming Territory. The valley in which it is situated stands nearly 7,000 ft. above the level of the sea at the base of the Uintah Mountains, which form its southern boundary; the Wind River Range defining it on the north-east, and the Wahsatch Mountains on the west separating it from the Great Salt Lake. The enclosed plain is evidently the remains of an extensive fresh-water lake, which in the Eocene period must have abounded with animal life, and whose borders must have been the haunts of animals, both huge and small, which lived and died by its marshy banks. Green River now runs through the plain, and it, with its smaller tributaries, by cutting up the easily eroded deposit, produces a scenery of a most peculiar character, consisting of flat-topped hills and cliffs, with perpendicular sides, and often most grotesque proportions. Those of the watercourses which do not dry up during the summer months are fringed with vegetation, such as cotton-wood, willow and aspen trees; but most of the country is treeless and barren, reminding the spectator more of the ruins of a colossal city, than of any other existing scenery.

The remains of mammals, which are very abundant, are mostly of genera which are not found elsewhere. Several, however, approach those of the Paris Tertiary basin. The odd-toed Ungulata, or Perissodactyla, are particularly numerous, whilst even-toed Ungulate or Artiodactyla are as remarkably few. True Proboscidians are not found, but if Prof. Marsh is correct in placing Dinoceras in an order by itself, animals equally huge, of an independent type, were far from uncommon. Most of the other mammalian orders are most probably represented, though much has yet to be done in the identification of specimens.

The results arrived at by American men of Science show that they deserve the careful study of English paleontologists and geologists, as they have already thrown great light on the fauna of the Tertiary period, and give promise of adding much more to our knowledge of that epoch, so important to the student of the anatomy and classification of the higher vertebrata.—*Abstract from Nature.*

GRIFFITHS' "GUIDE TO THE IRON TRADE OF GREAT BRITAIN." 8vo., pp. 315, illustrated. London: For sale by D. Van Nostrand. Price $10.50.

This is a very excellent work by Mr. Samuel Griffiths, editor of the "London Iron Trade Exchange," and besides supplying a deal of interesting information respecting the Iron and Hardware districts, it contains a general review of our mineral and metallurgical position in relation to the rest of the world, and also apt descriptions of the leading iron works and mineral districts, excellent illustrations of which are also given.

Considering the important position Great Britain holds as an iron-producing country, and as a great centre of trade with the whole world, Mr. Griffiths' figures will be particularly interesting, especially as he thoroughly explains the sources from which the vast supply is drawn, which he estimates to equal 50,000 millions a year, or £ 50,000 for each working day. In addition to describing the original use and present position of our iron districts, the author explains the value of the Bessemer steel system, the uses of the Birmingham and Glasgow exchanges, and gives the reader an insight into the Scotch iron warrant system of storing. Altogether considered, the "Guide to the Iron Trade of Great Britain" is a work of interest and utility, and will no doubt have a large circle of readers. The paper, type and illustrations are all that could be desired, and the binding

substantial, but we advise the addition of an index to future editions.—*Ironmonger.*

A TREATISE ON AN IMPROVED METHOD FOR OVERCOMING STEEP GRADIENTS ON RAILWAYS. By H. HANDYSIDE. London. For sale by D. Van Nostrand, price 40 cents.

Proposes to facilitate the use of steep gradients by utilizing all the power that can be obtained from the steam-pressure, and to devote it entirely to hauling the train without the engine up steep inclines of 1 in 10. In other words, it is proposed to transform the locomotive into a stationary engine, whenever and wherever it may be required, which, in that position, will be enabled to concentrate all its power in drawing up the train of carriages or wagons.—*Building News.*

MISCELLANEOUS.

DYNAMITE EXPERIMENTS. A number of very interesting experiments in blasting with dynamite were recently performed in the vicinity of Rossie Priory, on the estate of Lord Kinnaird, near Dundee. They were conducted at the request of Lord Kinnaird, and in the presence of many gentlemen, by Mr. John Downie, C. E., manager and secretary for the British Dynamite Company. Prior to commencing the experiments, Mr. Downie exhibited the dynamite and the cartridges formed of it, and the detonators and fuses used in its explosion, and he gave a brief account of the composition and properties of dynamite and the mode of using it as a blasting agent. He stated that large quantities of dynamite had been consumed in various Continental countries, in America, in Australia, and in this country, and that no accidents had occurred with it either in storage or in transit. It would not explode of itself, and though set fire to it would burn harmlessly away; even when ignited in a confined space it would still burn harmlessly, although it would expend its power more rapidly than in "the open." When one or two of the cartridges were opened it was found that the dynamite was soft and plastic, and of a reddish-brown color, somewhat similar to raw cane sugar. On applying a burning match to one of the cartridges it burned without any explosion, and left a greyish white residue consisting simply of the fine silicious earth known as kieselgühr, which is the medium in which the power of the really explosive substance, nitro-glycerine, is utilized in blasting. One of the detonators, which is an extra-powerful percussion cap, was fired by introducing a piece of Bickford fuse, and then igniting the free end of the same. A loud report ensued in the course of a few seconds, and Mr. Downie said that a few cartridges fired in a similar manner might be used for producing very loud reports at sea as distress signals.

In order to demonstrate more immediately the practical application of dynamite as a blasting material, to the satisfaction of the spectators, Mr. Downie tried it upon a number of tree roots, the trees themselves having been recently felled purposely for the experiments. By means of a crowbar, a hole was driven through the earth immediately underneath the principal mass of the root; two or three cartridges were thrown into the hole and rammed firmly home by means of a wooden rammer; then the "primer" cartridge, prepared in the usual way with the cap-tipped fuse, was introduced close up to the last cartridge; the opening around the protruding fuse was loosely tamped or stemmed with soil, and then the fuse was ignited. In a minute or two there was an explosion, attended by a low smothered report, and an upheaval of the tree root and the surrounding soil. The whole root was started, split as by wedges, and the ground all around was loosened, and to a considerable extent cleared. When the use of dynamite in blasting the roots of trees for land-clearing purposes was sufficiently demonstrated, the material was tried upon one of a number of very large boulders in an ancient ruin, by some persons regarded as Druidical, and by others as Roman. The dynamite was simply laid upon the top of the boulder, covered with a piece of turf, and fired in the usual way. No bore-hole was employed. The boulder was broken up most completely by the explosion, and started from its ancient seat.

The party afterwards proceeded to Hillton Whinstone Quarry, where a number of workmen were engaged in quarrying and dressing causeway blocks, and preparing whinstone for road-metal and concrete building. After inspecting the wire-rope railway, which was in operation conveying stones from the hill down to the stone-breaking machine in the Den, the party visited the stone-breaker itself, which was found to be driven by water power, and was breaking as much road-metal in a quarter of an hour as a single man could break in a week, and were greatly interested by what they saw. A number of bore holes in the face of the rock, previously prepared for blasting with gunpowder, were charged with dynamite in the usual manner. When the charges were fired, it was found, that at half the expense that would have been required for gunpowder, they had executed as much work as would have required two, three, or four times as much gunpowder or gun-cotton. Various experiments were also performed to show what could be done with dynamite in breaking up blocks of whinstone without making any bore-holes. It may be mentioned that the manipulation in nearly all the experiments after the first was done by some of Lord Kinnaird's own servants.

In the course of the day, Lord Kinnaird stated, that probably few people had had the opportunity of witnessing more blasting operations than he had seen during the time he was acting as a member of the Royal Commission of Inquiry into the condition of the mines of this country in the year 1862. One of the objects of the inquiry was to find a substitute for gunpowder, the fumes of which are very obnoxious and injurious to miners, and, he had no doubt, had dynamite been known at the time, the adoption of it would have been recommended by the Commission, owing to the innocuous character of the fumes resulting from an explosion of dynamite, which resemble those produced by gun-cotton in its explosion, an explosive that could not be recommended on account of its danger in use, and in its conveyance. His Lordship expressed himself as quite satisfied that no safer explosive material was ever brought under his notice; for, in consequence of its inert character, a powerful detonation was required in order to explode it.

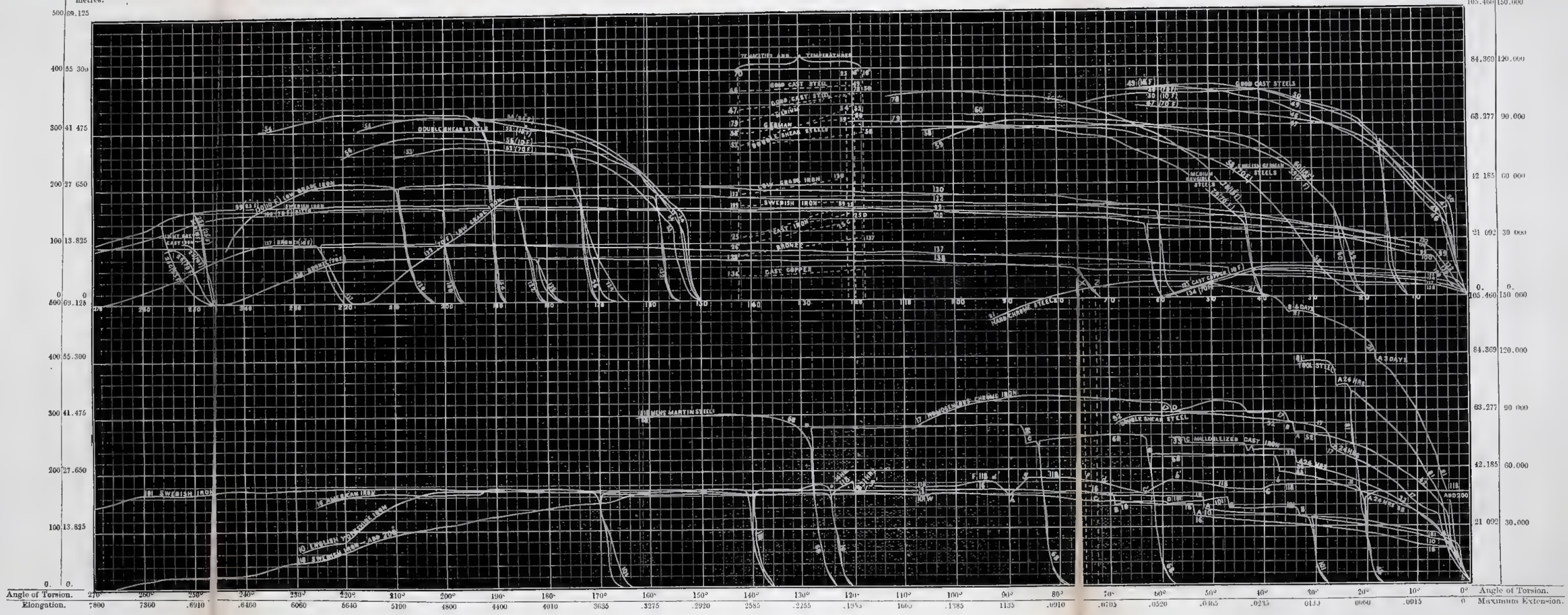
PLATE III.

AUTOGRAPHIC STRAIN-DIAGRAMS OF METALS,

ILLUSTRATING THE EFFECTS OF TIME AND OF TEMPERATURE UPON RUPTURE,

PRODUCED BY THE

TESTING MACHINE OF PROFESSOR R. H. THURSTON.



MATE ISTANCE.
Pounds per square th of Section.
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Torsion.
Extension.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. LXVIII.—AUGUST, 1874.—Vol. XI.

ON THE MECHANICAL PROPERTIES OF MATERIALS OF CONSTRUCTION, AND ON VARIOUS PREVIOUSLY UNOBSERVED PHENOMENA, NOTICED DURING EXPERIMENTAL RESEARCHES WITH A NEW TESTING MACHINE, WITH AUTOGRAPHIC REGISTRY.*

By Prof. R. H. THURSTON.

SECTION II.

14. *Introductory.* — The preceding section has been devoted to a description of the peculiar form of testing machine employed by the writer during these researches, to an account of the general method of obtaining from any material an autographic record of its mechanical properties, and to the interpretation of strain diagrams thus obtained from the useful metals and other materials of construction.

The part here presented contains an account of some of the more interesting and fruitful of the special investigations conducted with the apparatus, and embodies a description of certain remarkable and hitherto unobserved phenomena accompanying the distortion of metals, the discovery of which must affect the theory of the effect of stress in producing strain, and, consequently, must somewhat modify engineering practice.

15. *General Deductions.* — From what has already been shown, we may deduce the following *resumé* of methods of determining the several more important properties of materials by an inspection of their strain diagrams.

1. *To Determine the Homogeneousness of the Material.*—Examine the form of the initial portion of the diagram between the starting point and the sudden change of direction which has been shown to indicate the elastic limit. Notice also its inclination from the vertical and compare with it the inclination of the "elasticity line."

A perfectly straight line beneath the elastic limit, perfectly parallel with the "elasticity line," shows the material to be *homogeneous as to strain; i. e.*, to be free from internal strains, such as are produced by irregular and rapid cooling or by working too cold. Any variation from this line indicates the existence, and measures the amount, of strain. A line considerably curved as in No. 6, Plate I., exhibits the existence of such strain.

Next, examine the form of the curve immediately after passing the elastic limit. A line rising from the elastic limit, regularly and smoothly, approximately parabolic in form and concave toward the base line, as in No. 22, indicates *homogeneousness in structure*, and the absence of such imperfections as are produced in wrought-iron

*Transactions of American Society of Civil Engineers.

by cinder, or in cast metals which have been worked from ingots, by porosity of the ingot.

A line turning the corner sharply, when passing the elastic limit, and then running nearly or quite horizontal, as in other irons, and in the low steel of Plates II. and III., or actually becoming convex toward the base line, as with some of the woods in Plate I., and then, after a time, resuming upward movement by taking its proper parabolic path, indicates a decided want of this kind of homogeneity. The relative length of the depressed portion of the line, and the amount of depression, measures the relative defectiveness of materials compared in this respect.

Finally, compare the diagrams produced by several specimens of the same kind of material or from the same mass. Homogeneousness in general character and *homogeneousness in composition* are proven by the precise similarity of these diagrams, while a greater or less variation of the curves compared, indicates a greater or less difference in the specimens of which they are the autographs.

Materials should usually exhibit great homogeneousness in all these three ways, to be perfectly reliable. Perfect homogeneousness is nottobe expected in either respect.

2. *To Determine the Elastic Resistance of the Specimen.*—Measure the height of the curve at the elastic limit, using the scale of torsion, or for tension, which is given for each machine and for each standard size of test-piece, as shown in the accompanying plates.

3. *To Determine the Resistance offered to any given amount of Extension, or that producing a given set.*—Measure the ordinate of the curve at the point whose abscissa, or distance from the origin, measures the assumed degree of set.

4. *To Determine the Ultimate Resistance of the Material.*—Measure in a similar manner the maximum ordinate of the curve.

5. *To Determine the Resilience of the Piece within the Elastic Limit* (*i. e.*, the work required to produce an evident and permanent set, approximately proportional in amount to the degree of change of form of the specimen; this quantity measures the power of the material to resist blows, and its determination is evidently quite as important as that of resistance to static stress, which latter forms one of the factors of the former).—Measure the area comprised between the ordinate of the curve at the elastic limit and the initial part of the curve; this quantity is proportional to the required value. Or multiply the elastic resistance of the material by the extension within the elastic limit. As an approximate result, two-thirds this product is the quantity required in inch-pounds or foot-pounds, according as measures of extension are taken in inches or feet.

6. *To Determine the Resilience of the Material within any Assumed Limit of Extension* (*i. e.*, the magnitude of blow required to produce a given set).—Measure the area of the curve up to the assumed limit, as, for example, the area in Plate III., under No. 21, Z, 21, 21, Y, x, where the assumed set is the extension from Z to x. Two-thirds the product of the resistance measured by the altitude Yx, and the extension bx, gives, as before, an approximate value for ordinary purposes.

7. *To Determine the Total Resilience or Shock-Resisting Power of the Material.*—Measure the total area of the diagram. For ductile materials an approximate value is obtained by taking two-thirds the product of the maximum tenacity by the maximum extension. For hard and very brittle materials one-half the same product gives very accurately its values. For intermediate qualities the true value is more nearly two-thirds this product, also Swedish wrought-iron, white cast-iron, and hardened steel illustrate the first and the second classes; ordinary tool steels are examples of the third class, as is also iron like No. 22.

8. *To Determine the Effect of a Load given in pounds per square inch of stress.*—Find a point in the curve having an ordinate which measures the given stress. The abscissa of that point measures the extension under that load. In other words, a point being found in the curve, the height of which above the base line is equal to the load per square inch, its distance from the origin measures the extension of the material as produced by that stress.

9. *To Determine the Effect of a Blow or a Shock, whose measure is given in inch-pounds of energy* (*i. e.*, of which the work that it is capable of doing is known).—Find a point on the curve whose ordinate cuts off an area between itself and the origin, representing the given amount of work. Or find such a point that two-thirds

the product of the stress measured by its ordinate, and the extension corresponding to its abscissa, is equal to the number of inch-pounds given. The position of this point shows the maximum strain and the maximum extension of the material under the assumed conditions. Drawing a line through this point parallel to the nearest "elasticity line," the distance of the point at which it intersects the base line from the origin indicates the resulting set.

10. *To Determine the Effect of a Blow upon the Material, when already strained by a dead load.*—Determine first the extension produced by the application of the static stress, as in 8, and then find that point on the curve between the ordinate of which and the ordinate of the point indicating the strain just found as due the dead load, an area is intercepted which measures the work done by, or the energy of, the shock which has been assumed or calculated.

15. Examples.—Illustrations of the first seven of the above-described processes are either given in the preceding portions of this paper or will be noticed hereafter, during the progress of special researches. Those succeeding may be illustrated thus:

(1.) Given, a load of 30,000 lbs. per square inch. Determine its effect upon good qualities of cast and wrought iron, low steels, tool steel, and the weaker metals.

Referring to Plate II. for examples, we find that neither cast copper, lead, tin, nor zinc would sustain such strain; all would be broken.

Good irons, Nos. 1 and 6, would be strained beyond their limits of elasticity, and would take a set after an extension of about 1 and 1¼ per cent, respectively. The exceptional iron, No. 22, would be strained to a point which is so nearly its elastic limit that it would remain practically uninjured.

The low steels, Nos. 69, 67, 76, would bear the stress with a similar degree of safety, very nearly. The first would have a considerable margin of safety within its elastic limit; No. 67 would be nearly, and No. 76 would be quite, strained to the elastic limit, while No. 98 would take a set of about one-fifth of one per cent.

If the strain were torsional, the weaker metals would be twisted off by a force corresponding to that here assumed, the good irons would take a set of about 25 deg., the best iron and the three stronger steels would take no appreciable set, and the softest of the latter would set at about 10 deg. In these cases the specimens are supposed of standard size. For other sizes the forces producing similar effects would vary as the cubes of the diameters.

(2.) Given, the magnitude of a shock, or blow, *e. g.* as equal to that due a weight of one ton, 2,000 pounds, falling one foot, the rod taking the strain being of one sq. in. area of section and one ft. long. Determine the effect for each of the above-named materials.

The effect of this blow is equivalent to an expenditure of energy amounting to $2{,}000 \times 12 = 24{,}000$ inch-pounds.

The weaker materials, not possessing an ultimate resilience of this amount, would be broken.

Forged copper would be strained and would take a set after very nearly 12½ per cent. of extension, since

$$0.12\tfrac{1}{2} \times 12 \times \frac{24.000 \times 2}{3} = 24{,}000$$

the work done by the blow being equilibriated by the product of two-thirds the resistance, noted at 110 deg., Plate II., into the extension. Perfect accuracy of figures may be insured by perfectly accurate measurements.

The specimen of iron No. 1 would be given an extension and set of nearly 0.068, since the resistance, under this amount of stretch, would be approximately 45,000 pounds per square inch, and the work during extension would be

$$0.068 \times 12 \times \frac{45.000 \times 2}{3} = 24{,}000 \text{ inch-pounds.}$$

The iron of special grade No. 22 would be elongated $0.058 = 0.69$ inch, as

$$0.069 \times 12' \times \frac{52.000 \times 2}{3} = 24{,}000 \text{ nearly.}$$

The same blow would produce on the rod, if made of such steel as No. 69, an extension of $0.0384 \times 12 = 0.461$ inches, estimated thus,

$$+ = 24{,}000 \div \tfrac{2}{3}\, 78{,}000 = 0.461,$$

it being found by "trial and error," that the extension 0.0384 develops a maximum resistance of 78,500 pounds per sq. in.

It is evident that, where extreme accuracy is required, the curves should be transferred to a new scale in which the abscissas should be a scale of elongation instead of angular distortion, and the area should be

carefully measured.* For the latter work an Amsler "Planimeter"† is useful.

(3.) Given, a bolt of dimensions as last assumed, strained with the effect of a load of 30,000 lbs., as in example (1,) determine the effect of a blow of 24,000 inch-pounds energy, occurring while the bar is sustaining the static load.

The effect of the dead load, as already calculated, is to produce a strain upon the low steels, and upon iron like No. 22, which would keep them extended only a very minute fraction of their original length, this extension being, even with the latter material, but 0.05 of one per cent. The effect of the blow would be, practically, the same as has just been estimated for the unloaded bar.

Nos. 1 and 6 would be, as already shown, extended 1 and $1\frac{1}{2}$ per cent. respectively, by the simple load. The added effect of the blow would be to produce an additional extension and set of 0.0533 and 0.0555 respectively, since the mean resistance, during this extension, is

$$\frac{45{,}000 + 35{,}000}{2} \text{ and } \frac{42{,}000 + 30{,}000}{2}$$

respectively, and the extension must be,

$$24{,}000 \div \frac{45.000 + 30.000}{2} \div 12 = 0.0533 \text{ and}$$

$$24{,}000 \div \frac{42{,}000 + 30.000}{2} \div 12 = 0.0555$$

The bar is stretched in the first case 0.64 inch; in the second 0.666 inch, by the blow, if made of such iron as that of specimens Nos. 1 and 6.

It should be remarked here, that although the diagrams obtained from the various materials tested, give data from which to estimate their relative value in resisting shock, the absolute results of calculation, with no modification for varying rapidity of action, will be but approximate.

This is a consequence of the facts that the inertia of the body struck will effect the result, and that the actual resistance varies with the velocity of rupture. A rod which will sustain safely the blow of a heavy body, would yield readily under a blow of similar energy struck by a light weight moving with proportionally increased velocity. The mathematical investigation of this effect, which has not hitherto been noticed, remains to be given. It is only necessary to state here, that a rod of uniform section, and homogeneous in structure, will be uniformly extended by a force slowly applied. A blow received at one end will extend it most at the portion nearest that end, and the more rapid the blow the more is its effect concentrated. It is possible to produce actual fracture at one end by a very rapid blow, and for rupture to become complete before the shock is felt at the opposite end. This action is seen daily in every workshop where pieces are broken from heavy masses by the blow of a hammer.

The effect of a blow depends, therefore, not only on the magnitude of that product of mass into height due its velocity, which we call *vis viva*, but also upon the magnitude of the factors. It further follows that of two materials having equal tenacity and equal ductility, the one having greatest density will be most liable to fracture by impact.* This inference is confirmed by experience.

In general, a rod should be somewhat larger at the end receiving the shock, and this enlargement should be greater as the blow is more rapid. Conversely, blows of equal energy are the most injurious when given by bodies of light weight moving at high speed. This difference is exaggerated by any cause which increases the density of the material. The variation of resistance with the rapidity of rupture will be considered more at length hereafter.

It is readily seen that we have here an explanation of the fact, that fracture produced by a quick blow is granular in character, while a steady pull brings out the "fibrous" texture of iron. In the former case the action is concentrated upon a cross section close to the point at which the blow is received; in the latter instance inertia acts less effectively in resisting the transmission of the rupturing force to other portions of the piece, and the drawing out process is permitted to take place.

16. *Peculiar Problems* sometimes present themselves in practice which cannot be solved by any published methods—why, it is difficult to say, but partly, it is probable, because of a deficiency of experimental data, and partly because known authorities have not been led by actual experience in

* See London "Engineer," Nov. 8th, 1872.

† It is evident that diagrams accurately representing tests made with the common testing machine afford similar facilities for solving these problems.

* "Mechanics' Mag.", Dec., 1871, p. 492.

engineering practice to perceive the importance of their applications.

Of these the following is an example:

To determine the effect of a succession of stresses, whether static or dynamic, each of which strains the material beyond the original or the acquired limit of elasticity. —An illustration of this action is given by the repeated bending, stretching, or other form of distortion by external force, of any material producing at each application a new set. The same case is illustrated by the gradual elongation of a rod by repeated blows, the energy of each of which exceeds the elastic resilience of the material.

Determine the elastic resilience of the material existing previous to the application of each stress, by taking the area comprised between two lines drawn through that point on the curve of the material chosen, whose abscissa represents the existing extension, one of which lines is an ordinate and the other of which is parallel to the nearest "elasticity line." This area represents the elastic resilience of the piece; *i. e.*, a blow having an equivalent energy would leave the piece uninjured and without set. Deducting this amount from the energy of the given blow, the remainder of the work done by that blow is expended in producing set or extension, and may be determined as already described.

The effect of a simple force may be determined by deducting from the total distortion produced by each application of that force, the elastic range of the material.

It is thus readily ascertained, in either case, how much each application will add to the set, and how many applications will be required to produce rupture. It is here assumed that distortion within the elastic limit leaves the piece uninjured, however often it may be repeated. This assumption seems correct, *a priori*, and is well sustained by the valuable researches of Wohler* and others.†

The effect of repeated bending, or other form of strain, can thus be inferred from an examination of the strain diagram of the material, obtaining from a single experiment a determination hitherto only obtained by a long and tedious process of repeated distortion. Such investigations of the "fatigue" of metals are often of great importance.

17. *The effect of Time on Metals left under Strain.*—The effect of stress is modified when metals are left under strain for considerable intervals of time. It had generally been supposed that this effect was to weaken the resistance whenever the material was left exposed to a strain exceeding the elastic limit.

This idea seems sustained by the experiments of M. Vicat, made at Paris about forty years ago.* He states that four wires were extended, respectively, by $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, and $\frac{3}{4}$ their ultimate resistance, and their elongations were observed and recorded at intervals of one year. The relative extensions observed indicated a gradual lengthening of the three which were strained beyond the elastic limit, and that most strained finally broke after sustaining $\frac{3}{4}$ its original ultimate breaking weight two years and nine months, the point of rupture being finally determined by the action of corrosion which had not been entirely prevented.

The several extensions were as follows:

No. 1,	sustaining	$\frac{1}{4}$,	33	months	0.000 per cent.
No. 2,	"	$\frac{1}{3}$,	"	"	0.275 "
No. 3,	"	$\frac{1}{2}$,	"	"	0.409 "
No. 4,	"	$\frac{3}{4}$,	"	"	0.613 "

The rate of extension was nearly proportional to the times, and the total extension to the forces. M. Vicat concludes that metal thus overstrained will ultimately break, and his paper has caused much uneasiness among members of the profession, as indicating a possibility of the ultimate failure of structures having originally an ample factor of safety.

The elegant and valuable researches, also, of H. Tresca, on the flow of solids,† and the illustrations of this action almost daily noticed by every engineer, seem to lend confirmation to the supposition of Vicat.

The experimental researches of Prof. Joseph Henry, on the viscosity of materials, and which proved the possibility of the coexistence of strong cohesive forces with great fluidity,‡ long ago proved, also, the possibility of a behavior in solids, under the action of great force, analogous to that noted in more fluid substances.

* Zeitschrift fur Bauwesen Festigheitversucke mit Eisen und Stahl," Berlin; also Lond., 1860. "Engineering." 1871.

† Fairbairn: "Civil Engineer and Architect's Journal," Vols. XXIII., XXIV.

* "Annales de Chimie et de Physique," 1834; Tome 54, p. 35.

† "Sur l'Ecoulement des corps solides;" Paris, 1869-72.

‡ "Proc. Am. Phil. Society," 1844.

On the other hand, the researches of the writer, as described in the first section of this paper, indicating by the form of strain diagrams, that the progress of this flow was accompanied by increasing resistance, and the corroboratory evidence furnished by all carefully made experiments on tensile resistance, as those of King and Rodman, Kirkaldy and Styffe, made it appear extremely doubtful whether materials were really weakened by a continuance of any stress, not originally capable of producing incipient rupture.

18. To determine this point, a series of experiments were made, the general result of which was first formally announced in a note to this Society,* in which the first experiment, commenced during the session of the National Academy of Science at the Stevens Institute of Technology, was described, and in which the first deductions, since slightly modified by an extended investigation, were given. In Plate III., No. 16, is a *fac simile* of the strain diagram obtained at the first experiment.

A piece of iron, of a good quality of metal, but badly worked, as shown in the sketch already given in Section 1, was placed in the machine and strained considerably beyond its elastic limit. It was then left 24 hours under the strain thus produced at *A*, Plate III. At the end of this period, the pencil was found precisely as it was left, and not the slightest evidence of yielding was noted. The slight depression observed in many examples to be given, is produced by a slight compression of the wood used in blocking the machine at the beginning of the interval. No evidence of flow was therefore obtained.

Upon attempting to produce further change of form, however, the unexpected discovery was made that the test-piece had acquired an increased resisting power. The pencil, instead of following the general direction taken the day previous, rose, as seen in the diagram, until a resistance was indicated, *exceeding by nearly* 30 *per cent.* that shown before the specimen was left under strain. This resistance having been overcome, the piece yielded with a slightly decreasing resistance, and, after considerable additional distortion, was left at *B* 24 hours. The result of the second experiment is seen to be an increase of nearly 15 per cent., and a third trial at *C* gave a small, but still perceptible, gain also.

This singular phenomenon appeared so remarkable and so important that experiments were continued upon various grades of iron, and upon other metals, the greatest care being taken to avoid any possible source of error. Several strain diagrams are given illustrating some of these experiments.

No. 10 represents that of a piece of good iron which is far more homogeneous and better worked than No. 16.

No. 68 is a piece of "Siemens-Martin steel" which was left under strain, at *A*, 24 hours, and at *B* an equal length of time. In the latter case, the applied force was wholly removed, at the end of 24 hours, before an attempt was made to produce further change of form. On renewing the strain the resistance is seen to have acquired an increased intensity very nearly absolutely equal to that shown at *A*, and relatively greater, a fact which will be found to aid in the determination of the real character of the phenomenon. A third experiment at *C*, shows a repetition of this action, and a fourth, similar to that at *B*, in all except time—for in the last experiment the time was but a fraction of an hour—gave a similar result. In each case it is noticeable that a slight fall from the maximum attained, follows the yielding of the test-piece.

No. 33, malleable cast iron, No. 52, double shear steel, and No. 81, tool steel, all exhibit this same stiffening under prolonged strain.

No. 17, "homogeneous chrome iron," was subjected to experiment four times. At *A*, the effect is very marked, and the resistance to further change of shape continues to increase slowly until left at *B* for a second trial. The maximum attained at *B* is not sustained, as further distortion occurs, and, after a slight decrease, the specimen was again left, the pencil resting at *C*.

Next day, the increase of resistance was found less considerable than at the previous experiment, and the line, after passing a maximum a few degrees beyond, falls quite rapidly. Fearing that the metal was about to rupture completely, it was left once more at *D*, another day, after which time its behavior was similar to that on earlier trials. It fully regains the maximum power of resistance noted after the trial at *C*, and, before rupture, it even slightly exceeds it.

* "See Trans. Am Soc. C. E." Nov. 1873; "Journal Franklin Institute," March, 1874.

The hardest material experimented upon was the very hard chrome steel, No. 21. Left at *A* three days, the resistance at that degree of distortion was increased about 8 per cent., and, again at *B*, four days under strain gave a rise of nearly 4 per cent., after which a considerable rise occurred, in the ordinary manner, before rupture took place.

An interesting experiment was made with the best Swedish iron, a metal of such wonderful purity and ductility that one specimen, of standard size, was twisted nearly 600 deg. before completely breaking off.

No. 101, Plate III., is the strain diagram of the specimen tested for the purpose of determining the effect of continued stress. Here, as seems frequently the case, a loss of ductility apparently accompanies the increase of resistance and the total resilience appears to be comparatively slightly altered.

This specimen was strained until the limit of elasticity was just passed, and was then left at *A* one day. The result, with even the slight distortion of but 6 deg., producing an extension of a very minute amount, is similar to that before noticed, and the behavior here exhibited probably gives a clue to the causes of this peculiar action. After this trial, several others were made, and the metal is seen to have behaved in a manner precisely similar to the other grades of iron.

19. Reviewing all of the large number of experiments made since the discovery of this effect of continued strain, carefully comparing the curves obtained with each other, and with the diagrams obtained in the ordinary way, and, finally, making a comparison of the conclusions drawn from this research, with the results of the experimental work of other investigators, the writer has been led to the following, as the most probable explanation of this singular molecular phenomenon.

These strain diagrams are the *loci* of the successive limits of elasticity of metal, at successive positions of set.

The phenomenon here discovered is an elevation of the limit of elasticity by a continued strain. The cause is probably a gradual release of internal strain, occuring in a somewhat similar manner to that observed previously in cast iron in large masses, and less frequently, and generally in a less marked degree, in wrought-iron and other metals, which have been worked in large pieces, and in which such strain has been more or less reduced by a period of rest.* This loss of strength in large masses of wrought iron is stated, by Mallet, to amount frequently to one-half.†

20. The manner in which this reduction of internal strain occurs, by continued stress at the limit of elasticity, as here observed, may be readily conceived.

When the metal is thus strained, many sets of molecules are placed in positions in which they exert a maximum effect tending to produce molecular changes which may equalize the originally irregular distribution of inter-molecular stresses. After a time, the change actually takes place by "flow," and the resisting power of the piece becomes increased, and its limit of elasticity raised, simply because its forces are now no longer divided, and may act together in resisting external forces. The diagram itself exhibits the best evidence of the occurrence of flow, but it is also shown by an inspection of the broken specimen, as in Figures 6, 7, and 11, of Section I.

It was at first suspected that an action had been detected in this phenomenon, similar to that by which the "portative force" of a magnet is increased by loading its keeper more and more heavily until it becomes "supersaturated." It is not impossible, perhaps not improbable, that the two cases are similar in some respects, this behavior of the cohesive force in the present example, aiding to produce the extraordinary increase of resisting power here observed.

A comparison of the ductility registered by samples variously treated lends some confirmation to the supposition, formerly expressed, that, in all cases, the resilience does not increase in the same proportion as the increase of mean resistance, as a consequence of sustained stress, and this, if a a fact, may possibly be considered as corroborating the idea just suggested.‡

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* Compare London "Iron," Stability of Iron Structures, Feb, 1874; Van Nostrand's Magazine, April, 1874.

† "On the Co-efficients of Elasticity and Rupture in Wrought Iron in Relation to the Volume of the Mass, its metallurgic Treatment and the axial Direction of the constituent Crystals."—*Proc. Inst., C. E.*

‡ Since the above was written, the "Journal of the Franklin Institute" has, in the issue for March, 1874, given an account of experiments made by Commander Beardslee, U.S N., during which metal strained beyond the elastic limit by tension, exhibited a gain of resistance at a position of earliest set, *i.e.*, an elevation of the elastic limit, from 23.075 to 26,100 pounds per square inch, 13 1 per cent., in seventeen hours. The material was bloom iron turned approximately to one-half square inch section.

A very important fact noted by the experimenter is that an

The discovery of this elevation of the elastic limit in all metals examined is also probably confirmatory of this idea.

If the explanation, just offered, of the apparent strengthening action of prolonged stress is correct, the conclusions of Vicat are not overthrown, although evidently not fully justified by his own experiments, and although the intervening forty years of engineering practice have not produced evidence which may be considered as confirmatory of them.

The same molecular movement, or flow, which rearranges the internal forces and relieves internal strain, may be a phase of that viscosity which Vicat supposed might in time permit rupture of metal, subjected to stress nearly approaching its original ultimate resistance, the one action being a more immediate result than the other, and the latter producing its effect, even when cohesive force may have been actually intensified.

Should this prove to be the fact, it would seem allowable to conclude that the forces of polarity and cohesion are not identical. The cause of the apparent increase of strength of iron, with increase of temperature, is seen to be explained by this relief of internal strain, which occurs most readily at high temperatures.

The experiments of the writer have not indicated the possibility of continued flow, and, consequently of ultimate rupture, except under stress, increasing in intensity up to the full maximum resistance of the material.* They no not, therefore, confirm Vicat's deductions, and the inference would seem, on the contrary, to be—that structures of metal do not become weakened with age, except as injury occurs by corrosion, or by overloading. The experiments of Roebling † and his opinion, as expressed in his report on the Niagara Suspension Bridge, are apparently correct.

Kirkaldy, also, concludes that the additional time occupied in testing certain specimens of which he determined the elongation "had no injurious effect in lessening the amount of breaking strain." ‡ An examination of his tables shows those bars which were longest under strain to have had highest average resistance.

21. Wertheim supposed that greater resistance was offered to rapidly, than to slowly, produced rupture; Kirkaldy concludes that the contrary is the case. Redtenbacher § and Weisbach ‖ assume the law of resistance to be the same beyond the limit of elasticity as within it, and deduce formulas for resistance to shock which are widely inaccurate.

The experiments of the writer prove that, as had already been indicated by Kirkaldy (whose results, however, had been looked on by many of the profession with some suspicion), a lower resistance is offered as the stress is more rapidly applied. This conspires with *vis viva* to produce rupture.

This is seen at *w*, No. 101, Plate III., where a sudden increase of velocity produced a depression of the line, at the angle 110 deg., and it is exhibited in a much more marked degree in No. 118.

In the latter example, the strain was gradually applied until the point *a* was reached, when, with a suddenly applied force, a motion estimated at about one-tenth of a foot per second, was obtained, and, immediately at *b*, the resistance fell off very considerably, the pencil dropping to *c*. Again resuming the slowest movement, about one hundreth of a foot or less per second, resistance rose again to *d*. A repetition of the rapid movement between *b* and b^1, was followed by a loss of resistance again from b^1 to c^1, and, as is seen by the diagram, this occurred whenever the experiment was repeated. At *k*, distortion by a very slow movement was resumed, and continued until the specimen broke. Here we have, probably, the first direct determination of this question, in which the effect of *vis viva* does not appear.

We may therefore conclude that the rapidity of action, in cases of shock, and where materials sustain live loads, is a very important element in the determination of their resisting power, not only for the reason given already in paragraph 3 of this section, but because *the more rapidly the metal is ruptured, the less is its resistance*

apparent positive action was observed in the metal under strain by which the scale beam was actually thrown up by a force measuring 125 pounds If this observation is not erroneous, or, if the action was not due to some accidental circumstance, we may have here a measure of the *intensifying effect* above described.

Commander Beardslee has communicated to the writer the experimental confirmation of the fact, deducible from the explanation here given, that this release of internal strain occurs to a nearly equal extent if the strained piece is simply laid aside for a similar interval after it has been given a set.

* Compare Kirkaldy—"Experiments on Wrought Iron and Steel"—pp 62–69; also see the plates given by Styffe, exhibiting curves for tension.

† "Journal Franklin Institute," 1860; Vol. XL., p. 360.

‡ "Experiments on Wrought Iron and Steel," pp 62, 83.

§ "Der Maschimenbau," Vol. 1

‖ "Mechanics on Engineering," etc.

to rupture. This loss of resistance is about 15 per cent.* in No. 118.

The cause of this action we may presume to bear a close relation to that operating to produce the opposite phenomenon of the elevation of the elastic limit by prolonged stress, and it may probably be simply another illustration of the effect of internal strain.

With a very slow distortion, the "flow" already described occurs, and but a small amount of internal strain may be produced, since, by the action noticed when left at rest, this strain relieves itself as rapidly as produced. A more rapid distortion produces internal strain more rapidly than relief can take place, and the more quickly it occurs, the less thoroughly can it be relieved, and the more is the total resistance of the piece reduced. Evidence confirmatory of this explanation is found in the fact that bodies most homogeneous as to strain exhibited the least of these effects.

It does not seem impossible that, at extremely high velocities, the most ductile substances may exhibit similar behavior, when fractured by shock, or by a suddenly applied force, to substances which are really comparatively brittle.

In the production of this effect, which has been frequently observed in the fracture of iron, although the cause has not been recognized, the inertia of the mass attacked and the actual depreciation of resisting power just observed, conspire to produce results which would seem quite inexplicable except for the evidently great concentration of energy here referred to, which, in consequence of this conspiring of inertia and reduced resistance, brings the total effort upon a comparatively limited portion of the material, producing the short fracture with its granular surfaces, which is the well-known characteristic of sudden rupture.

Any cause acting to produce increased density, as reduction of temperature, evidently must intensify this action of suddenly applied stress.

The liability of machinery and structures to injury by shock is thus greatly increased, and it is quite uncertain what is the proper factor of safety to adopt in cases in which the shocks are rapidly produced. This uncertainty must remain until further experiment shall be made the basis of a correct mathematical expression of the natural laws involved in the problem.

Meantime, the precautions to be taken by the engineer are: To prevent the occurrence of shock as far as possible, and to use in parts exposed to shock, light and elastic members, composed of the most ductile materials available, giving them such forms as shall distribute the distortion as uniformly and as widely as possible.

22. The behavior of materials subjected to sudden strain is thus seen to be so considerably modified by both internal and external conditions, which are themselves variable in character, that it may still prove quite difficult to obtain mathematical expressions for the laws governing them. It is not improbable, however, that an approximation, of sufficient accuracy for all cases which frequently arise in practice, may be obtained by a study and comparison of experimental results obtained, as above, by the method here adopted, and one which seems peculiarly adapted to the work.

A carefully-conducted series of experiments giving quantitative results would be of great value. Without such a research no reliable knowledge can be obtained of the law of depreciation, and no useful formulas can be devised for use in calculation. The experiments made by the writer are not yet sufficiently numerous or precise to serve as data from which to deduce equations.

23. The Elasticity of the Metals.—The examination of the "elasticity line" will be found to present some facts of interest.

It will be seen that, in every case, the line produced by the descent of the pencil is not precisely coincident with that formed by its rise. This is not due to the friction of the machine, as that would not cause the decided difference observable in the form of the curve. It may be partly due to the fact that the set produced is partly temporary.*

An attempt was made to determine its law by the following method:

A steam gauge having a recording apparatus, in which the paper was moved horizontally, at a uniform rate, by a well-constructed clock, was kindly furnished by the Messrs. Edson, of the New York Recording Gauge Co.

This was set up by the side of the machine, upon a stand on which could be

* Compare Kirkaldy, p. 83, where experiments, which are possibly affected by the action of *vis viva*, indicate a very similar effect.

* Morin, "Resistance des Materiaux," p. 10.

clamped the test piece. The latter carried a light, long pencil holder, so arranged as to traverse the paper in a direction at right angles to that of the motion given it by the clock. An angular motion in the specimen of 0.05 deg. would be readily observed. The specimen was given a degree of torsion of from 10 deg. to 360 deg., in different cases, and was then rapidly transferred to the stand where the restoration of form would record itself upon the moving paper, forming a curve of which the ordinates would represent the restoration of form, and the abscissas would be proportional to the time.

In all cases observed, the restoration of form, by loss of temporary set, was so rapid as to have become completed before the specimen could be placed in the recording apparatus, and the record made a straight line invariably.

The conclusion which has finally been deduced from a study of the diagrams obtained is, that the peculiar feature here alluded to is a consequence of an internal molecular friction, the existence of which has already been long suspected by the writer, and probably by many other experimenters.

An illustration of a similar action probably occurs in the behavior of iron under magnetic action. Magnetization produced in bars of various qualities of iron and steel during important researches of Dr. Joule* and Prof. Tyndal,† proved this behavior to be common to all, when the change of form was produced, within a very minute range even, by magnetic force. Dr. Mayer has more recently‡ examined this peculiar form of molecular action with great skill and thoroughness. Its existence is undoubtedly well proven, and the lines, above referred to, on the strain-diagrams seem to exhibit its effect very clearly. Possibly the rise from *f* to *g*, No. 118, Plate III., is due to such friction.

24. The evident proof found, in the parallelism of all elasticity lines in each diagram, of the fact, first noted by some of the earliest experimenters in this field, that elasticy remains quite unimpaired up to the point at which rupture commences, has been already adverted to.

Coulomb describes a series of curious and instructive experiments which may assist in determining the molecular action occurring in these instances where great distortion and great permanent displacement of particles takes place without loss of elasticity.*

He found this to occur, not only with metal wires, but with threads of fine clay, 1-12 of an in. in diameter and 11 ft. long, which could be twisted $5\frac{1}{2}$ turns repeatedly without set and without apparent loss of elasticity. Turning the thread through a wider range of torsion, it always returned but $5\frac{1}{2}$ revolutions, and in each new position of set exhibited the same elasticity as before.

The explanation of this action, as illustrated by the strain diagrams of Plates II. and III. and by Coulomb's experiments, is probably also to be found in the phenomenon of flow of solids. The restoration of cohesion, in bodies actually separated, exhibits the extent to which this action may proceed. Two freshly cut surfaces of lead when brought together, with a moderate pressure cohere firmly, and plates of glass, laid one upon another, sometimes "seize" each other so firmly that they are cut and worked as one piece.† The welding of iron is another and a very familiar illustration of the same action. Cohesion may therefore be actually destroyed and renewed, and molecules may move among each other, changing completely their relative positions, without loss of either strength or elasticity.

The result of these experiments on metal are important as exhibiting the error of the opinion hitherto entertained by many physicists and engineers, among whom was the writer,‡ that straining metal might weaken it, even when rupture did not commence, and even where no condition of internal strain was induced. It has been here shown that elasticity remains unimpaired, and resistance continually increases up to the point at which incipient fracture takes place. No well proven exception to this law has been observed.

25. While comparing the inclination of the elasticity lines with the initial line, to determine the pressure and the amount of internal strain, it has been noticed that more or less strain seems almost invariably to exist, but that the amount, as indicated

* "Philosophical Magazine;" 1874.
† "Researches on Diamagnetism," etc., 1870.
‡ "Effects of Magnetism in changing dimensions of iron and steel bars," by A. M. Mayer, Ph. D.; Stevens Institute of Technology; 1872. "American Journal of Science and Arts;" 1873.

* "Lecture Notes on Physics;" Mayer. "Journal Franklyn Institute," 1868.
† Miller: "Chemical Physics;" p. 67.
‡ "Journal Franklin Institute."

by the difference in inclination of the two lines, is not always as well shown by the greater or less curvature of the initial portion of the diagram. The probable reason would seem to be that this strain is not always uniformly distributed. Were the strain considerable and uniformly distributed, the initial line would be strongly convex toward the base line, and would have the parabolic form. Absence of strain is indicated by a straight line rising regularly to the elastic limit, or, in many cases where the elastic limit is very low, and when the material is inelastic and flows without tendency to recoil, concave toward the base, and parabolic. Irregularly distributed strain would modify the parabolic curve, and the amount of strain would determine the total curvature.

The initial and elasticity lines have, therefore, great interest as revealing important and otherwise unrecognizable properties of the material.

It has been remarked that the difference of inclination just referred to, proves the truth of the assertion of Hodgkinson that every load produces a set. It can now be readily seen why this should usually be the fact, and also that, although it is true, it does not necessarily indicate injury of the material.

Since, in its ordinary state, many sets of particles are usually in a condition of maximum strain, the slightest application of external force to the piece will destroy the existing equilibrium among these conflicting forces within the mass, producing a change of form, and either rupturing or producing a flow of those particles which are most strained, and thus causing a new condition of equilibrium, the piece returning only approximately to the original form when relieved. The greater or less the applied force, the greater or less the number of displaced particles, but it is only when the set becomes nearly proportional to the distortion that it assumes the character in which it is looked upon as a serious effect.

With perfectly homogeneous materials, free from internal strain, no such action would be noticed, and the earliest set would occur beyond the elastic limit, which limit is here considered to be attained when the set becomes proportional to the distortion.

26. The very minute range of distortion within the elastic limit is shown by the strain-diagrams very beautifully. This point is usually reached with the first 5 deg. of torsion, and where internal strain has been eliminated it is frequently found within 2 deg., the corresponding extension being much less than .0001.

Captain Rodman, who has made the most delicate determination yet published,* detects a set of 0.0000014 after an extension of 0.00027 in a specimen of cast-iron, and the elastic limit, as here defined, is reached after an elongation of about 0.0003, the point not being, however, very accurately determinable on account of the insensible change of rate, as already observed in the strain-diagrams of cast-iron.

The immense magnification, on the strain-diagrams, obtained with the torsion machine, of the elongation at the commencement of the curve enables the behavior of the materials within this minute, yet most important, portion of the entire range, to be perfectly represented, and permits its examination in a most satisfactory manner.

27. *The Influence of Variations of Temperature.*—The effect upon the mechanical properties of metal of variations of temperature has long been a subject of debate, and one which has not even yet been satisfactorily settled by experiment.

A priori it would appear that, in a perfectly homogeneous material, entirely free from internal strain, change of temperature would produce an alteration of strength and of ductility which would both be the reverse, in direction, of the variation of temperature.

The forces acting to produce mechanical changes being, probably, cohesive force, on the one hand, resisting external forces tending to produce distortion or rupture, while the force produced by the energy of heat motion conspires with external force to produce that distortion, and the molecules being, at every instant, in equilibrium between the force of cohesion, on the one side, and the sum of the other two forces mentioned, on the other, variations of form must ensue with every change in the relative magnitude of these forces. A change of temperature produced by an increment of heat energy, it would appear, must produce a reduction of cohesion by separation of particles, and the opposite change must cause an increase of cohesion by their ap-

* "Experiments on Metals for Cannon," etc., Rodman, pp. 157-167.

proximation. Increase of temperature, by reducing the range of action of cohesion by separating particles, and causing them to approach the limit of reach of cohesive force, would reduce ductility, and the opposite change of temperature would increase extensibility. The effect on resilience, the product of ductility and strength, would evidently be still more marked than the variation of its factors.

The peculiar behavior of zinc, and the often observed brittleness of iron, at low temperatures, have given cause for doubting the truth of the above statement, and until the phenomena accompanying variations in homogeneousness of structure and composition, and the introduction or removal of internal strain, have been very thoroughly investigated, it cannot be anticipated that the subject will become well understood. The character of polarity—that force of which the presence constitutes the distinguishing difference between solids and liquids—remains to be determined, and its determination may be expected to throw important light upon this subject.

Experiments of both physicists and engineers have failed, up to the present time, to give as much and as precise information as is needed to determine satisfactorily what rules should govern the proportions of structures, whether carrying dead loads or subjected to shocks or blows, at any given temperature below the usual range, or even at the low temperatures to be met during every winter in the latitude of New York.

In a paper recently published* on "Molecular Changes produced by Variations of Temperature," the writer gave the results of a careful investigation of the experimental work previously done, by both philosophers and engineers, in researches bearing upon this important question.

28. The conclusions, as there reached, were the following:

1. That the number and the nature of those molecular forces which determine the physical condition of matter are not yet fully ascertained, but that these forces manifest themselves in, at least, three distinct modes of action, and, as thus exhibited, they are known as repulsion, cohesion, and polarity.

2. That the force of repulsion is, apparently, heat motion, or some closely-related phase of energy. That the force of cohesion bears some resemblance to that of gravitation, but seems not to be identical with the latter; and that the force of molecular polarity, which determines the molecular relations of position, seems to bear some distant relation to that of magnetic polarity.

3. That the law which governs the variations in intensity of these forces with changes of intermolecular distances, is undetermined, and that it has not been expressed by any mathematical formula, except approximately, and for a limited range.

4. That the magnitudes of the intermolecular spaces, and consequently the volume of any mass, are variable with changes in the relative magnitudes of the forces of cohesion and repulsion.

5. That the resistance offered to change of form is determined by the relations in intensity of the forces of polarity and those forces which determine intermolecular distances.

6. That, at the "absolute zero" (—461.2 deg. Fahr.), cohesion, and consequently the strength, of the material has, probably, its maximum value, heat-energy having disappeared.

7. That, at very high temperatures, heat-energy exerts a separating force upon particles, which entirely overcomes the other forces, and matter, assuming the gaseous state, requires the action of extraneous forces to preserve its volume unchanged.

8. That, at intermediate points, matter, in either the solid or the liquid state, exhibits a definite degree of separation of molecules which is determined by the intensity of the repulsion due to heat motion, a position of equilibrium being assumed, which, with the same substance, is invariable for the same temperature. The application of some kind of force is required to disturb this equilibrium and to produce change of volume. The amount of this force is determined, for any given extent of disturbance, by the maximum value of cohesion for the substance and the quantity of heat which has been required to raise it from the absolute zero of temperature.

The sum of the applied force and the force consequent upon the presence of heat motion must exceed cohesive force to produce dilatation, while this cohesive force, added to externally-applied force, must ex-

* "Iron Age," June, 1873; "Van Nostrand's Mag.," July, 1873; "Jour. Frank. Inst.," 1873; "London Jour.," Jan., 1874. Also in pamphlet, p. 29. D. Van Nostrand.

ceed the force of repulsion to produce diminution of volume.

9. That the distinction between the solid and liquid states of matter seems due to the action, in the former, of the force of polarity, which gives stability of form, while, in the latter, this force is extremely feeble, disappearing altogether when the boundary line between the liquid and gaseous states is reached.

That combined stability and elasticity of volume may be produced by the equilibrium of attractive and repulsive forces, but that stability and elasticity of form demand the co-existence of cohesion and polarity.

10. That the general effect of increase or decrease of temperature is, with solid bodies, to decrease or increase their power of resistance to rupture, or to change of form, and their capability of sustaining "dead" loads.

11. That the general effect of change of temperature is to produce change of ductility, and, consequently, change of resilience, or power of resisting shocks and of carrying "live" loads. This change is usually opposite in direction and greater in degree than the variation simultaneously occurring in tenacity.

12. That marked exceptions to this general law have been noted, but that it seems invariably the fact that, wherever an exception is observed in the influence upon tenacity, an exception may also be detected in the effect upon resilience. Causes which produce increase of strength seem also to produce a simultaneous decrease of ductility, and *vice versa*.

13. That experiments upon copper, so far as they have been carried, indicate that (as to tenacity) the general law holds good with that metal.

14. That iron exhibits marked deviations from the law between ordinary temperatures and a point somewhere between 500 deg. and 600 deg. Fahr., the strength increasing between these limits to the extent of about 15 per cent. with good iron. The variation becomes more marked and the results more irregular as the metal is more impure.

15. That above 600 deg. F. and below 70 deg., the general law holds good for iron, its tenacity increasing with diminishing temperature below the latter point, at the rate of from 0.02 to 0.03 per cent. for each degree Fahrenheit, while its resilience decreases in a higher but not well determined ratio for good iron, and to the extent of reduction to one-third its ordinary value, or less, at 10 deg. F. when cold short, and, in the latter case, the set may be less than one-fourth that noted at a temperature of 84 deg. Fahr.

16. That the viscosity, ductility and resilience of metals are determined by identical conditions, and that the fracture of iron at low temperatures has, accordingly, been found to be characteristic of a brittle material, while, at higher temperatures, it exhibits the appearance peculiar to ductile and somewhat viscous substances. The metal breaks in the first case, with slight permanent set and a short granular fracture, and in the latter with frequently a considerable set and a form of fracture indicating great ductility. The variation in the behavior of iron, as it approaches a welding heat, illustrates the latter condition in the most complete manner.

17. That the precise action of the elements with which iron is liable to be contaminated, and the extent to which they modify its behavior under varying temperature, remain to be fully investigated, but that the presence of phosphorus, and of other substances producing "cold shortness," exaggerates, to a great degree, the effects of low temperature in producing loss of toughness and resilience.

18. That the modifications of the general law with other metals than iron and copper, and in the case of alloys, have not been studied and are entirely unknown.

19. That these conclusions are sustained by experiments of both physicists and engineers.

"The practical result of the whole investigation is that iron and copper, and probably other metals, do not lose their power of sustaining "dead" loads at low temperatures; but that they do lose to a very serious extent their power of sustaining shocks or of resisting sharp blows, and that the factors of safety in structures need not to be increased in the former case, where exposure to severe cold is apprehended, but that machinery, rails and other constructions which are to resist shocks, should have larger factors of safety, and should be most carefully protected, if possible, from extreme temperatures."

29. The conclusions above given were deduced from the physical investigations of Boscovitch, Coulomb, Henry, Powell, Cagniard de la Tour, Andrews, Faraday, Wartman, Robison, Gaudin, Thompson, Rankine

and others, and from the more purely technical researches of Professors Johnson and Norton, Fairbairn, Kirkaldy, Brockbank, Joule, Spence, Styffe and Sandberg.

An apparent discrepancy of results from which some experiments seemed to indicate weakness, and others strength of metals as a consequence of reduced temperature, was explained by the fact that those which seemed to prove the first conclusion, were cases in which the metal was tested by blows, and those proving the reverse were tests made by steady strain. The deduction 11, made above, that the result of change of temperature, by producing changes of ductility, which were the reverse of those produced in tenacity, and that the same bar might thus exhibit a higher resistance to static stress while less capable of resisting shock, explained the seeming contradiction.

30. It was evident that, to determine satisfactorily the real effect of changes of temperature, it was necessary to obtain a series of experimental determinations of the simultaneous action of such variations upon both strength and resilience. Such experiments could readily be made by the method here pursued, and a considerable number of observations are represented by strain-diagrams on Plate III.

In these experiments, the machine and the test pieces were placed in the open air, where, changing in temperature with the atmospheric changes, no error could arise by transfer of heat during the experiments. The machine and the specimens submitted to test were always of the same temperature.

The mildness of the past winter has precluded the determination of the behavior of iron at temperatures very far below the freezing point, the lowest reached being 10 deg. Fahr.

This is the more to be regretted, since, as will be seen, there exists a possible change of law near the Fahrenheit zero, and it is extremely important to ascertain whether this indication of an anomaly arises from irregularity in the quality of specimens, nominally of the same grade, or whether it is a real variation of the effect of change of temperature.

As no previously made experiments combine, in the manner here presented, the various effects of heat upon the mechanical properties of the metals, the results obtained are given as a beginning, and the conclusions which are deduced from them are given as merely probable, while it is to be hoped that other members of the profession, who may be so situated that they can readily continue the work at points in the north and northwest where a temperature far below zero is reached, will make more complete and instructive researches during succeeding winters.

It is apparently quite impossible to avoid error if the attempt is made to experiment with specimens cooled down by freezing mixtures, and the writer would only feel justified in presenting the results of out-of-door work.

31. Referring to Plate III., the strain-diagrams of the best, and of medium tool steel, of German and double shear, of the several grades of iron and of copper and bronze are given, for temperatures from 70 deg. down to 10 deg. Fahr. A diagram is also given in which the horizontal scale of the plate is taken to represent absolute temperatures on a one-fourth scale, and at ordinates representing respectively 10 deg., 18 deg., 25 deg. and 70 deg., the resistances of the several specimens are laid off, and dotted lines connecting them indicate the rate of variation of strength with temperature.

It will be seen that with the single exception of a scrap gray cast iron, presumably unusually impure (Nos. 25, 26), the effect seems invariably to have been a simultaneous increase of both strength and ductility with decrease of temperature to 18 deg. and usually to 10 deg. from 70 deg. Fahr. In the case of the cast-iron, the increase of tenacity and reduction of ductility at the lower temperature are equally well exhibited, and the result is a slight decrease of resilience.

It will be noticed that the general trend of the lines in the diagram prepared for comparison of results, is very evidently towards a point on the scale (250 deg.), corresponding to a temperature of 1,000 deg. above the absolute zero, at which point, were the diminutions proportioned to temperature, the metals would lose all cohesion. Since, however, the law, as determined approximately by the Committee of the Franklin Institute, is expressed by a parabolic equation, the fact that their melting points are nearer 3,000 deg. or perhaps 4,000 deg. Fahr. above the absolute zero, does not conflict with the results of experiments.

32. Comparing the several specimens of "good cast-steel," it is found that the four (Nos. 46, 47, 49, 50) whose strain-diagrams are given, evidently differ nearly as much in their individual properties as in their alteration by temperature. The two pieces tested at 70 deg. Fahr. give a mean of strength, ductility and resilience, which is less than either of the other specimens. The strongest piece was broken at 18 deg., while that tested at 10 deg. is very nearly its equal in that respect, and is more than 10 per cent. better in extensibility and nearly 10 per cent. superior in resilience. The difference between the specimens tried at 10 deg. and at 70 deg. (average of the two) is about 15 per cent. in ductility and resilience, and rather more than 5 per cent. in tenacity. The piece tested at 10 deg. has a limit of elasticity exceeding that of the specimens tested at 70 deg. in about the same proportion.

The double shear steels are irregular, as would be expected from their method of production, but the greatest ductility is shown by the specimen tested at 25 deg. F., and the greatest tenacity by that broken at 25 deg. also. The weakest is that tested at 70 deg., its loss of strength, ductility and resilience, being very striking. The position of the elastic limit varied with that of the ultimate strength. "German" (English) steel exhibits greatest strength at 18 deg. (No. 60), greatest ductility at 70 deg. (No. 58), and greatest resilience at 25 deg. (No. 25).

"Medium crucible" steels seem strongest at 18 deg. Fahr., most ductile and equally resilient at 25 deg., and weakest, least ductile and least resilient at 70 deg.; Nos. 78, 54, 70 are their strain-diagrams.

Swedish irons (Nos. 99 and 100) were tried at 25 deg. and 70 deg., and the result is again that the greatest resistance and greatest extensibility occur at the lowest temperature, the difference here amounting to something less than 10 per cent. at the elastic limit and about one-half as much at the maximum.

A piece of common iron was selected by the blacksmith from his stock as "the worst specimen of cold short iron in the shop." The two specimens, Nos. 130 and 132, were taken from the bar and tested at 10 deg. and 70 deg. Fahr., respectively, with a result which is unexpectedly similar to those already given in the variation of ultimate strength, ductility, and resilience. The increase of strength at the lower temperature is apparently nearly 15 per cent., the increase of ductility about the same, and the increase of resilience 30 per cent. At the elastic limit this is reversed, however, the specimen tested at 70 deg. showing the highest elastic resistance. That broken at 10 deg. exhibits a very considerable amount of internal strain, to the presence of which may be attributed the exceptional behavior of these pieces. A similar difference, but opposite in direction and less in amount, is noticeable in the Swedish irons, Nos. 99 and 100.

Copper, Nos. 133 and 134, and bronze, Nos. 137, 138, both show a considerably greater strength at 10 deg. than at 70 deg., and a slightly improved ductility. The increase of tenacity and resilience amounts to 20 per cent. and 30 per cent. respectively, the ratio being slightly greater at the limit of elasticity.

Cast iron exhibits the most striking increase of tenacity, the ratio of increase being above 30 per cent, and in ductility having a mean value of 50 per cent. One specimen, No. 25 *C*, has a serious defect of internal strain, but, eliminating that by cutting off the sharply-curved lower portion of the line, it would coincide very exactly with the companion specimen, No. 25 *D*, broken at the same temperature, 25 deg.

33. It would seem, after a study of these experiments and after a comparison with those described by other experimenters, that, although a considerable irregularity, due to differences in material nominally of identical character, tends to obscure them, we may feel some confidence in drawing the following conclusions in modification and extension of those already given in article 28.

(20.) That, with pure, well-worked metals, the principle enunciated in article 28 is fully illustrated, and a decrease of temperature is accompanied by increase of strength, ductility and resilience.

(21.) That materials which are impure and irregular in character may exhibit exceptions to, and even reversals of, that principle in changes of ductility, and, while increasing in power of resisting simple stress, may lose their power of resisting shock, by a diminution of temperature.

We may hence feel confidence that, with really good iron or steel, we are not exposed to seriously increased danger of failure of structures at such low temperatures as frequently occur in this latitude.

There is no reason to believe that the familiar effect of phosphorus in "cold shortening" iron and steel, when cold, has its maximum effect at ordinary temperatures. The experiments of Sandberg would seem to prove this effect to be intensified continually with decrease of temperature.

34. Since the above research was concluded, the writer has become indebted to the thoughtful kindness of Mr. Chas. Francis Adams, Jr., for reports, one of which is that of the Mass. R. R. Commissioners for 1874, containing (page 144, *et seq.*) the result of an investigation of the cause of rail breakage on a considerable number of railroads in the United States and Canada. The conclusions given are that "cold does not make iron or steel brittle, or unreliable, for mechanical purposes," and that "it was not the rule that the most breakages occur on the coldest days." The introduction of steel in place of iron rails, has caused an almost complete cessation of the breakage of rails (p. 150).

The deduction which would seem proper in comparing these latter statements with the work of Sandberg would seem to be, simply, that the latter experimented with cold short rails. The same conclusion is given in Sandberg's own statement of the difference between Welsh and French metal.*

35. We still require, to give us reliable information regarding exceptional cases, a series of experiments to determine the action of excessively low temperature, and whether the apparent change of law near the Fahrenheit zero is a natural or an artificial phenomenon. We need to learn precisely the effects of sulphur, phosphorus, and silicon at extremely low temperatures. We need, also, and especially, to learn by experiment, whether extremely low temperatures occurring during our winters, produce a serious effect upon iron and steel by the introduction of internal strain as the material decreases in volume and increases in density.

The uncertainty still existing as to the extent to which increased density at low temperatures and reduction of tenacity under sudden strains at all temperatures—phenomena which have been revealed but not measured during the investigations here described—will be recognized by every member of our profession as one which it is exceedingly important to remove. It is hoped that it may not long remain, for it is evident that, although perhaps improbable, it is not impossible that, notwithstanding the increase of both tenacity and ductility by reduction of temperature, these causes may still conspire to produce increased tendency to yield before shock at some unknown low temperature.

36. The peculiarities of fracture, which have been alluded to, are exhibited in the accompanying Plate.

Figures 15 and 16 exhibit the behavior of a bar of iron made at Catasauqua, Pennsylvania, as broken by Mr. Oliver Williams, at 70 deg., and, again, at 20 deg. Fahr. It is selected from among the specimens in the cabinets of the Stevens Institute of Technology. The fracture at 70 deg. (Figure 15) has the fibrous fracture and all the characteristics of what is generally considered a tough and ductile iron. That at 20 deg. (Figure 16) resembles the break produced by a quick blow in good iron, or by any treatment at ordinary temperatures of a cold short iron. Were the conditions stated not known it would be supposed that irons like Nos. 1 and 16, Figures 5 and 6, were combined in a single bar.

Figures 17 and 18 illustrate strikingly the difference between the specimens of copper, Nos. 87 and 133, which have been already described, and of which the strain-diagram of the one is shown in Plate II., and of the other in Plate III. No. 87 was cast in green sand, and broken at 70 deg. Fahr., while the other was made from the same ingot, but cast in dry sand and broken at 10 deg. Fahr.

The first is unsound in structure in consequence of the dampness of the mould, and exhibits a peculiar radiated texture which is probably due to the same cause. The second is distinguished by its compact, homogeneous structure, probably due to the freedom of the mould from vapor and gases. It presents a beautiful crystalline fracture, which is probably due partially, if not principally, to the low temperature at which it was broken.

These fractures are extremely interesting from the strongly typical features which they exhibit as characteristic of the peculiar conditions under which they were produced.

RESUME.

37. *En résumé*, a review of this investi-

* P. 157; conclusion 3; p. 158, line 4; p. 132, Nos. 21, 24.

affecting, the distortion and rupture of metals, it would seem allowable to accept, as extremely probable, the following

GENERAL CONCLUSIONS.

1. That accurate strain-diagrams, in which the behavior of the material, as distortion progresses, and especially about the elastic limit, afford a means of acquiring valuable information respecting the strength, elasticity, homogeneousness, ductility and resilience of materials, and of tracing the modifications induced by variations of treatment and of composition.

2. That internal strain plays a most important part in determining the behavior of materials strained by either static or dynamic stress.

3. That the time during which applied stress acts, is an important element in determining its effect, not only as an element which modifies the effect of the *vis viva* of the attacking force and the action of inertia of the piece attacked, but, also, as modifying seriously the conditions of production and relief of internal strain by even simple stresses.

4. That with good materials, cold does not produce injury, but actually improves their power of resisting stress and increases their resilience.

5. That the influence of impurities, of various methods of manufacture, of changes of density with temperature, and of the causes which produce a concentration of the action of rapidly produced distortion and of quick blows, are subjects which still require careful investigation.

6. That experiment confirms the theory as to the behavior of materials, homogeneous in composition, structure, and strain, as expressed *à priori* in 27, and hence a probable deduction that the force of molecular repulsion is heat motion.

ON SIMPLICITY AS THE ESSENTIAL ELEMENT OF SAFETY AND EFFICIENCY IN THE WORKING OF RAILWAYS.

By Captain HENRY WHATLEY TYLER.

(*Continued from page* 87.)

The next branch of the subject is that which refers to the preservation of intervals between the trains. It is obvious that as long as any interval, whether of time or space, is actually preserved between any two trains, they cannot come into collision with one another. Collisions are liable to occur between trains following each other on the same line of rails; or, within fixed signals, at stations, sidings, junctions, etc. The greatest number of collisions occur at stations or sidings, and within fixed signals. In 1872 there were 91 cases of collisions at stations or sidings, 32 cases at junctions, 22 cases from trains following one another, 5 from trains meeting in opposite directions, and 34 from passenger trains being wrongly turned into sidings or otherwise through facing-points—out of a total of 238 train accidents investigated by the Board of Trade.

As soon as trains were run with sufficient frequency to endanger one another, it became obviously necessary to establish some system of preserving intervals between them; and the practice obtained of allowing a certain number of minutes to elapse, not only between their times of starting, but also between the times at which they should pass intermediate stations, and any junctions, or level-crossings in charge of gate-keepers, or other points at which servants of the companies were stationed; and the plate-layers were also on many lines expected to warn any train which appeared to be following too closely upon a preceding train. In tunnels it was further found necessary to prevent one train from entering at one end until the preceding train had passed out at the other end, and this was the commencement of what is called the block system, by means of which an interval of space was secured, in place of an interval of time, between the trains. The time interval which came to be generally adopted was 5 minutes of danger and 5 minutes of caution; that is to say, the trains were to be kept 5 minutes apart from one another in their running, and were to be cautioned if they were not 10 minutes apart. But in the case of goods or slow trains preceding fast non-stopping trains, still greater intervals were required; and sometimes periods of 15 or 20, or more, minutes, became, as the differences in speed increased, insufficient

safely to admit of heavy goods trains being started in front of express passenger trains. It was recognized at an early period that the simplest and best mode of avoiding collisions at stations and sidings was by keeping the main lines clear for passenger trains; and accordingly it was provided in the regulations that the main lines should not be interfered with, in the way of obstructions or shunting, within 10 min. of a passenger train being due, and, sometimes, within 15 min. of an express train being due. The proposal to divide the line into telegraphic sections, and thus to preserve space intervals between trains, was made by Mr. (now Sir William) Cooke, as far back as 1842, and was first practised, it is believed, on a portion of what is now the Great Eastern Railway, in 1844; and, subsequently, a train telegraph system was established on portions of the London and North-Western Railway. This latter, however, was not a block system, or a space system, but a time system worked with the aid of telegraph instruments; and it is now known as the permissive system. Under this system, the line between London and Rugby was divided into sections averaging rather more than two miles in length, and the signalmen were required to telegraph the trains to one another—to turn their signals to danger on the passage of every train—keep them at danger for 3 min., or more in certain special cases—to exhibit caution signals after the expiration of the 3 min.—and only to give clear signals again after receiving "line clear" from the next cabin in advance. In the case of tunnels, no second train was allowed to enter until the preceding train had been signalled as "out," and a space system was thus introduced; but on other sections two or more trains were allowed to be travelling at the same time; and even if a second train reached a cabin before a preceding train had passed the next cabin, and within the three minutes prescribed for the exhibition of the danger signal, the engine driver was, after his train had been brought to a stand, to be warned of a train in advance and to be allowed to proceed. This system is worked by needle instruments, the needles being pegged over to "line blocked" or "line clear," as the case may be; and the vertical position of the needle is taken to indicate, either that the telegraph is out of order, or that the line is obstructed. On certain telegraph posts special loops of the telegraph wires are provided, to be broken by the guards or brakesmen of trains in the event of sudden obstructions; and in long tunnels the loops are inclosed in boxes at intervals of about 100 yards. By breaking these loops, the guards or brakesmen are enabled to inform the signalmen at either end of a section, of an up-line, or a down-line, or a third line, or two or three lines, being suddenly obstructed by an accident to a train.

As regards the block system, there are many descriptions of means of instruments for working it, and various rules and regulations applicable to it on different lines of railway. The main principle involved is, simply, by the division of a line into block sections, and by allowing no engine or train to enter a block section until the previous engine has quitted it, to preserve an absolute interval of space between engines and trains. This may be done mechanically or electrically. Any means of communication with which the signalmen may be provided will enable them to inform one another of the approach of a train, of its entrance into a block section at one end, and of its exit from that block section at the other end. The raising or lowering of signal arms inside or outside the cabins, the beats on mechanical gongs or bells, the beats on electric gongs or bells, or the working of different descriptions of telegraph needles or instruments, may any of them be employed to afford indications of this description. But in many cases it is considered necessary to give further information, such as the description of the train, whether a through or stopping passenger train, or a goods or mineral train, or a ballast train, or a light engine; and to provide, besides the signals for line clear or line blocked, separate indications also for an acknowledgment signal, for an attention signal, for an obstruction signal, for an error signal, for a testing signal, for notice of shunting going on at a station, for a train to be shunted out of the way to allow another to pass it, or for a train to be stopped and examined in the event of something suspicious or wrong having been observed in it. Then, again, on some lines distinction is made between passenger trains, express goods or cattle trains, through goods or mineral trains, stopping goods, mineral, or ballast trains, and as to whether these are approaching, or whether they have entered the section. These and other indications are differently

made on different lines. In some cases the block instruments are used for them; in some cases they are made exclusively on electric bells; in some cases single-needle speaking instruments are employed. On certain lines, the block system is used for the protection of junctions; no two trains which could come into collision with one another being allowed to approach a junction at the same time. On other lines it is not so used, or is only used in the case of junctions approached on heavy falling gradients, or, under other circumstances of extra risk. On some lines record books or registers of the trains are carefully kept, and are found to be valuable safeguards against irregularities, the working of each signalman being checked by the record book of the signalman on each side of him. On other lines record books are not employed. Certain railways are worked on the block system by bells only; others by bells and block instruments, so as to afford the aid and evidence of sight as well as sound to the signalmen; and others by bells, block instruments, and speaking instruments. When the bell code includes a great number of indications, then the number of beats required, amounting to 10, or even 14 and 15, become so numerous that the men are liable to mistakes in counting them; and especially with the system sometimes employed of making, for instance, six beats mean one thing and three beats twice repeated, some other thing. It is, in any case, all important that the two indications "line clear" and "line blocked" (from whatever cause) should be entirely distinct from all other signals; and the necessity for this was demonstrated in a recent accident, one cause of which was that an acknowledgment signal was mistaken for a line clear signal. One important question in the working of block systems is, the particular time when line clear should be given after an engine or train has passed a section cabin or signal. The lengths of the sections vary, necessarily, according to the nature of the traffic and with local circumstances. They may be measured by miles in some cases, and by yards in other cases. Whatever their lengths, if one train has passed out of a section before another train is admitted to it, there must at the period of admission of the second train be an interval of space equal to the length of the section between the two trains. But, supposing the first train, on passing out of the section, to be brought to a stand immediately after passing the section signal, then the second train, being admitted to the section, may also run up to that section signal and to the tail of the preceding train, and the interval between the trains will be reduced to nil. An engine-driver, overrunning a signal to only a slight extent, may, in such a case, come into collision with a preceding train. Different companies meet this question in different ways. On some railways the line is considered clear when the last vehicle of a train has passed the section signal; on other lines this is the case except during fogs and snowstorms; on others, again, different specified stations are differently provided for; and on other lines a difference is made in this respect between goods and passenger trains. The Northeastern rule, for instance, runs as follows: "In regard to passenger trains, the line in the rear section must always be considered blocked until the preceding train has either been shunted clear off the main line or has passed the advance semaphore where such signal is provided, or, where there is no advance semaphore, has passed the section home signal at least 300 yards on its journey in the next section." The question of protection by the distant signals in the case of trains so brought to a stand beyond the home or section signals, or in the case of an obstruction in a block section, formed the subject of a memorial in August, 1873, by the engine-drivers in the employment of this company, and the officers of the company appear to have acceded to the reasonable demand in this respect, of their engine-drivers.

The following is a copy, as received at the Board of Trade, of this memorial addressed to Mr. Fletcher, Locomotive Superintendent of the North-Eastern Railway, and stated to have been signed by 650 engine-men on that railway:—

"We, the undersigned, engine-men under your employ, beg most respectfully to ask you to intercede on our behalf for the better working of the block signals, as the way it is worked is contrary to the working on all other railways, and should the same practice be continued, the most disastrous consequences may ensue as bad weather approaches.

"What we complain of is the not working of the auxiliary or distant signal when a train is required to stop, as it is impossible to stop at the home signal if the distant signals are not worked, as we cannot see

the home signals at many stations and block cabins till we approach within a short distance of them; and likewise we beg to call your attention to the slackness of the auxiliary wires at stations and block cabins as well, as they are kept so slack they will not raise the signals as we can understand them.

"Sir,—Should you not be able to get any of these bad arrangements altered, will you, please, cause more time to run the trains, so that we can stop at all cabins to ascertain if the road is clear for our safety as well as the public at large.

"We remain,

"Your most humble and obedient servants,

"ENGINE-MEN IN YOUR EMPLOY."

It is interesting to observe in this case that the engine-drivers, who are likely, as we are sometimes told, to become reckless in working under the block system, themselves took steps to induce their superiors to alter regulations which were not, in their opinion, and as the result of their experience, sufficient to enable them to work with confidence and safety. They appear virtually to have declined to work, and to be trained to work, under a system of risk to which, in their opinion, the regulations of the company—which differed from those of other companies—exposed them. But it is to be hoped that those who were concerned, and took part in this question, will relate accurately and fully what occurred; and what were the views of the engine-drivers on the one hand, and of the superior officers of the company on the other hand, on this subject. A strong desire also was expressed to the author in the course of a recent inquiry, on the part of the engine-drivers of the London and North-Western Railway, running with fast through trains, to receive a caution signal, say at block-station A, when the line is not clear between block-stations B and C; or, in other words, to receive an additional section of warning by a caution signal in the event of an obstruction; as well as to have a greater proportion of break-power under their command. A tail-board by day as well as a tail-lamp by night is of great value in enabling each signalman to see at a glance as a train passes him whether the whole of it has gone by, and is now very commonly employed.

In the working of single lines by telegraph, a risk is incurred which does not arise in the case of double lines. In the event of irregularities in the running of the trains, it becomes necessary to alter the crossing places of trains proceeding in opposite directions; and from time to time accidents have occurred in this country and elsewhere in consequence of misunderstandings in making such alterations. Such accidents led many years since to the establishment of, and to the preference by many for, the train-staff system of working single lines. In some cases a combination of train-staff and block-telegraph has been adopted, and this combination appears to afford, when it can be carried out, the greatest degree of safety. But the feeling in favor of working single lines by telegraph only appears again to have strengthened; and it must be admitted that it allows of greater freedom in dealing with the traffic, especially on lines of considerable length. It is most extensively practised in America, in India, and on the Continent of Europe.

Of all the difficulties that present themselves in railway working, the greatest is that of running trains in a fog. When the fog is so thick as to prevent the engine-drivers from seeing the signals, it then becomes necessary to inform them by other means of their condition; and, accordingly, plate-layers or porters are employed as fog-men, to stand near the signals, to place detonating signals on the rails, and thus to inform the engine-drivers of the indications of the signals; or they convey in some cases verbal directions from the signalmen. The greatest difficulty and danger are incurred either when a fog comes suddenly on, and the fog-men are not at their posts, or when it lasts for a long time, and the fog-men are required for duty for an excessive number of hours. The system is at best an unsatisfactory one. Much ingenuity has been displayed, and numerous proposals have been made, with a view to supplying audible signals, detonating or otherwise, to be worked mechanically with the ordinary signals, and thus to afford additional indications to the engine-drivers. But there is always danger in trusting to expedients which are exceptionally employed; and it can hardly be contemplated, in any case, to make every signal on a railway audible as well as visible, either ordinarily or exceptionally, to the engine-driver. Such complications of sounds as would result at busy places might indeed raise an outcry. The running of fast trains at high speed through a thick fog,

must, under any circumstances, with or without the block system, be attended with great risk; and the only practical arrangement appears to be to cause the speed of the trains to be reduced, during fog, according to its density, and according to circumstances; and to improve the organization of fog-men and their duties. Some of the companies do not allow the use of great-coats to men employed in winter on such duties.

There are, then, many points worthy of discussion as to the best mode of carrying out the details in the working of the block system. It has been found essential on very crowded lines, in tunnels, and other places of extra risk. The outcry against it of those chairmen of railway companies who at the same time take credit for its adoption, and who are indebted to it for the comparative safety of the traffic on the most crowded portions of their lines, cannot be considered to be very serious. The system of presumed time intervals has failed, because those intervals could not in practice be preserved; and the permissive system for reducing the time intervals by the aid of the telegraph, and sending trains timed to travel, and capable of travelling, at various speeds, one after another, into the sections, with a caution to each, may also be considered to have failed, because it does not afford sufficient protection to the traffic.

Under these time systems, collisions have occurred from engine-drivers slackening their speed to avoid collision with trains in front of them, and being run into by trains behind them. The greater the variety of speed between the trains, the more does the weakness of such systems become apparent. They may at first sight appear simple, but they involve constant confusion and uncertainty, because it is impossible to calculate in railway working upon the time intervals which it is safe to allow between trains under ever-varying circumstances; and no rules can possibly be laid down to meet all cases. Simplicity in working is, after all, best obtained by a system which will secure intervals of space between the trains; but a sufficient margin of space should be preserved between them at the end of a block-section as well as at the beginning of it; and to avoid confusion in working, not only should the signalmen have control over the traffic, but also the engine-drivers should have ample command of their trains; and there should further be lines and sidings sufficient to enable the work to be performed without disobedience to the regulations, and under good discipline. One great advantage, in fact, of the introduction of the block system lies in the necessary and simultaneous introduction of extra accommodation and appliances, without which it cannot be properly worked.

The safety of railway traffic from the great majority of serious accidents—namely, from various descriptions of collision and from accidents in connection with facing-points—thus depends mainly upon two classes of men, and upon the apparatus, the means, and appliances with which they are supplied. These two classes of men are the signalmen and the engine-drivers. The engine-drivers rely upon the signalmen to give them the proper indications, by means of their signals, as to whether the lines are clear or obstructed—as to whether the points are right or wrong; and the signalmen rely upon the engine-drivers to look out for and obey the signals that are made to them. The safe working of the traffic in this respect depends, therefore, upon a thorough understanding between these two classes of men. It depends, in fact, on the avoidance of mistakes, misapprehensions, or neglect (1) in the observance of signals by engine-drivers, (2) in the working of points and signals by signalmen, and (3) in the communications of signalmen with one another. In order to obtain the greatest degree of safety, it is necessary, as far as possible, to reduce the risk of such misunderstandings and neglect; or, in other words, pains must be taken to avoid confusion in working, and to substitute for it simplicity in working. Confusion in working must be more or less the consequence when rules and regulations are in force which cannot be carried out in practice—when hand-signals intended for one engine-driver may be received and acted upon by another engine-driver—when there is not a fixed signal for each purpose for which a signal is required—when signalmen or pointsmen are obliged to run about station-yards, at serious personal risk, to work points and signals, without being certain as to what train may next approach them, or when it may be expected—when, having a number of levers without locking apparatus in or around the cabin, they are liable to pull the wrong signals and point levers over for an approaching train—when, in the absence of necessary means

of communication, neighboring signalmen are liable to work at cross purposes with each other—when, in the absence of sufficient goods lines and sidings, station-masters and signalmen are compelled to allow the shunting, sorting, and marshalling operations of goods trains to be performed on the passenger lines, or goods trains to be moved from one main line to another, while passenger trains are due or overdue in one or both directions—when engine-drivers of through trains or stopping trains, at junctions or sidings, have not reliable signals, properly placed, to inform them distinctly, in each case, when they must stop or when they may go forward——when, under the permissive, or any other time system, they are told of trains being two, three, or any other number of minutes of time in front of them, without knowing how fast such trains may be able to travel, or what trains may similarly be allowed to follow them, and therefore what speed they should themselves maintain to avoid, on the one hand, a collision with a train in front, or, on the other hand, a collision with a train behind them—when, in long, heavy trains, timed to travel at high speed, they have not sufficient brake-power to enable them to bring the train to a stand within a reasonable distance—when they cannot depend upon the guard hearing their brake-whistles, and have only a limited proportion of retarding power under their own control—when the lines cannot be kept clear for them at stations at which they are not due to stop—and when they find it difficult to maintain their time-table speed, and at the same time to approach each and every signal in the course of their journeys with the requisite amount of caution, according to the severity of the gradients, the slipperiness of the rails, the proportion of break-power, and the positions of and view afforded by such signals.

These elements of confusion in working, far from being theoretical or imaginary, have too often been practically illustrated by lamentable accidents on various systems of railways; and it is in the endeavor to avoid such confusion that the modern recommendations and requirements of the Board of Trade and its officers have gradually, as the result of experience over a great number of years in observing these causes of accidents, grown to their present condition. The object of these recommendations and requirements is to substitute simplicity for such confusion, as a means of greater safety and efficiency in working. Simplicity in working has thus been obtained in a very great number of cases, and has yet to be obtained in many other cases. It consists, as regards signalmen, in affording to each signalman, by proper signal and point arrangements, complete control over the lines, sidings, and traffic at his post; in preventing him from making such mistakes in the handling of his levers as may lead to accidents—mistakes which the most careful men are liable to commit sooner or later, if they are not protected by locking apparatus, but which they are in a great measure prevented from making by such apparatus; in giving him sufficient warning of the approach of trains from different directions; in providing sufficient accommodation on lines and sidings to enable the main lines to be kept clear for the passenger trains. It consists, as regards the engine-drivers, in arranging that each shall have a distinct signal to look to for every necessary purpose, and that he shall have the means of properly obeying it, without any inducement to run risk in disobeying it. It cannot, of course be expected, even when the utmost simplicity in working is arrived at, that there will be no more accidents to deplore, because, unfortunately, human agency must still be relied on, and human agency must always be, as it has ever been, fallible. So long as engine-drivers are men, they will occasionally run past signals; so long as signalmen are human, they will occasionally make mistakes and misunderstand one another. Neither the block system nor locking apparatus will, as the author has frequently stated, be a panacea for preventing railway accidents altogether; nor can any other improvements be expected to have such an effect. But it is equally certain that the number of serious accidents may be very much reduced, and especially on certain railway systems, when all the improvements above referred to have been carried out. The risk of the mistakes of signalmen in working points and signals will have been in a great measure neutralized. Goods trains will not so much encumber the passenger lines, and will not be engaged in shunting on them, and crossing from one main line to another, when passenger trains are due; and this, of itself, by a simpler form of working, will tend to prevent a large proportion of accidents. De-

lays will thus be avoided also, both to passenger and to goods trains, and greater efficiency in working will be obtained. And this is no mere matter of speculation, because greater safety and efficiency have been and are obtained on those railways or portions of railways on which such improvements have already been introduced.

But it is necessary to consider next the arguments that are put forward in opposition to such improvements; and I may commence with the remarks which were addressed to the Institution of Civil Engineers by the President, on his recently taking the chair after his election to that office. When Mr. Harrison attributes to the author that he does not sufficiently appreciate the element of human frailty as contributing to accidents on railways, and leaves it to be understood that improved arrangements will not materially lessen the number of accidents and their serious results, the author would venture to reply that he estimates that cause of accident at no more and no less than has actually been found by the experience of many years to attach to it. There are, no doubt, as there always will be, accidents which occur from the inattention, mistakes, or neglect of officers or servants after all possible means have been provided for securing safety; but these form the smaller proportion, and in too many cases such mistakes or neglect arise in working under defective, and even glaringly defective arrangements; while, on the other hand, it is marvellous to observe for how long a period those officers and servants whose fallibility is thus considered to be underestimated frequently carry on their work under such defective arrangements without causing accidents of a serious character. Inefficient men are sometimes found also at most important posts. The wonder really is—and it is only fair to them plainly to say so—that the men who do the real practical work on the railways have made so few mistakes, when they have in so many cases been unprovided with proper means of performing their work. In order fully to prove the truth of this position, it would be necessary to adduce the experience of many years, which would occupy too much space here; but it will be sufficient for the present purpose to cite a few prominent cases in illustration of it, and some of them may be taken from the history of the North-Eastern Railway. The attention of that company appeared first to be seriously awakened to the necessity of interlocking point and signal levers on their existing lines, though they had for many years been necessarily doing it on their new lines, after the fatal accident at Thirsk, on the 9th of May, 1869, when a Scotch express train from the south ran through a pair of facing-points into a siding near the station, instead of pursuing its course along the main line. The signalman clearly could not have made the mistake which caused that accident if the lever by which the facing-points were worked had been interlocked with the levers for working the signals. He would in that case have been unable to lower his signals until he had first set the facing-points in the proper direction. Then, again, the collision at Brockley Whins, on the 6th of December, 1870, was one of the most disastrous in its results that ever happened on the North-Eastern Railway. In that case, an express up-passenger train and a down coal train, due to pass on opposite directions on two main lines without stopping, were turned into each other on a cross-over-road between these two lines. The collision was due, no doubt, to a mistake of the signalman, but under circumstances which would hardly be credited if they had not caused the accident. The signalman was provided with one lever for working together the two facing-points, one on each of those main lines, and thus with the means of the more easily turning the trains into one another and producing the accident; whilst that lever was not interlocked with the signal levers, so as to prevent him from lowering signals whilst the facing-points were set in this dangerous position. Five persons were killed, and fifty-nine were injured, as the result of this example of simplicity in construction and confusion in working. Turning to other railways, the fatal collision on the 29th of June, 1867, at the Walton Junction, on the main line of the London and North-Western Railway—the most costly collision, as regards the amount of compensation, that ever occurred on that railway, in which eight passengers lost their lives and seventy were injured—would have been prevented if the signals and points had been interlocked. The adoption of this precaution had been specially recommended for the same junction by the author, on the occasion of a previous collision on the 1st of January, 1862, in the words quoted near the commencement of

the present paper. Then, again, there was the collision at Kirtlebridge, in 1872, the worst example on the Caledonian Railway, in which eleven persons were killed and fifteen were injured, and which will, it is said, when all claims have been settled, cost the company about £50,000. In this latter case, the station-master himself turned a shunting goods train across into the way of a night express train from London for Scotland, after a signalman at a distance from him had lowered the signals to allow it to pass. But the station-master would not have made this fatal mistake, and it could not have been made at all if the points had been worked from a cabin, and if the lever for working them had been interlocked with signal levers. These are a few instances which must, it is true, be set down to mistakes of officers or servants, but in which this element of human fallibility might and would have been completely neutralized if only points and signals had been interlocked with one another, and if thus simplicity had been substituted for confusion in working.

Another recent illustration of the arguments employed against such improvements in railway working is contained in the half-yearly speeches of Sir Edward Watkin, and, coming from so practical an authority, they ought to be worthy of special attention. In addressing the shareholders of the Manchester, Sheffield, and Lincolnshire Railway, at Manchester, on the 28th January, 1874, Sir Edward Watkin is reported in the "Railway News" to have said that the Board of Trade "assumed that men were infallible instead of fallible; that they were always awake and attentive, and that they never could by any possibility make a mistake." Now it will be at once apparent that if the Board of Trade had any such conviction its officers would not have thought it necessary, for instance, to require that signal levers and point levers should be interlocked with one another, because if men were really infallible, they would never pull over the wrong lever, and in that case the serious accidents above cited would, in fact, never have occurred. It is precisely because human agents are fallible that the various precautions referred to are required to counteract as far as possible the element of such fallibility; and it is for that reason that locking and other arrangements become necessary. It is hardly necessary to say that Sir Edward Watkin has no warrant for making such an assertion, which, indeed, he himself partially refuted—according to the same newspaper—at the half-yearly meeting, on the following day, of the South-Eastern Railway Company. He then made a very different allegation in saying:—"But where the Board of Trade's heresy is, is in believing that by the adoption of mechanical appliances you can insure almost absolute safety." So that the Board of Trade has two heresies—one in assuming the men to be infallible, and an opposite one in trusting to mechanical appliances. But he goes on himself to express confidence in mechanism:—

"I say it is heresy because it overlooks the fact that you have to work without military discipline your 8,000 or 10,000 men who are fallible. It is the mistakes of those men which cause the accidents, and not the failure of mechanism or deficiencies in the strength or endurance of material."

And again:

"My notion of railway working is simplicity. These things increase complication. The Board of Trade requirements tend to make the thing complex, to make it difficult, and to multiply the causes which lead to error; and I think myself, if you will take the average of ten years after we have got all these new-fangled things into operation, it will be shown that the old, simple arrangements of Stephenson, Brunel, and Locke are best; and, after all our experience, we may have to come back to the simple way of working, and to put many of these new-fangled things into the fire."

The author recently heard of an observation even more extraordinary than the above, which was addressed, not long since, by an aged Field-Marshal to a still more aged retired Lord Chancellor, as they were walking together at Hampton Court, and which was related to him by a friend who was with them. In the midst of earnest conversation in a loud tone—for they are both rather deaf—the Field-Marshal suddenly stopped, and thumping his umbrella violently on the ground, said impressively, with evident reference to a bygone period, "When I went to see the Dook at Walmer, the Dook said that railways would never answer in this country; and, you see, here's this Wigan accident. The Dook was right." This sentiment is, in one sense, on a par with Sir Edward Watkin's proposal to "put many of these new-fangled things into the fire," and to return to the sim-

plicity of older days. Exactly to what period of simplicity he would revert he does not point out; whether to the days of no signals at all, and to the system of the fireman jumping off the engine to push over the switches, without the aid of a lever; or to any particular epoch between that time and the present, he does not specify. But, seriously, can he believe, as chairman of the South-Eastern and the Metropolitan Railways, that by putting the apparatus—complicated, no doubt, in construction, but simple in working, as compared with the duties to be performed—into the fire; by doing away with the locking apparatus and the block system at Charing Cross and Cannon Street, and at the various complicated stations on the Metropolitan Railway, with trains following each other and crossing the path of each other within periods numbered sometimes by minutes and sometimes by seconds, that the traffic could be carried on at all? He would find that not one day, nay, in some places, not one hour, would pass without a serious accident and a complete block to the traffic. And, indeed, the author has had occasion himself to inquire into two accidents which have so occurred, during a temporary want of the apparatus, on the occasion of alterations or repairs.

Sir Edward Watkin's remarks were anything but complimentary to the common sense of his shareholders, and they were an insult to the memory of the illustrious engineers whose honored names he dragged into such an argument. They would never have proposed to work the traffic of the present day with the simple arrangements of former times. Speaking specially of the block system he further says:

"It is very good, but it has a weakness I have often pointed out, namely, that it leads on the part of our servants to too great reliance on the machinery, and a weakening of the reliance on themselves."

And he takes credit for the South-Eastern Company—as other chairmen have done for other companies—for having been the first to adopt his system. He says:

"But if there is any credit to be taken for the block system, I am here to tell you that the credit belongs to you, for the first railway in England (before the Board of Trade found out that there was any good in it) that adopted the block system was the South-Eastern, and the first railway that completed their line was the South-Eastern. We got no hints from the Board of Trade. We acted on our experience, and it has been a valuable advantage (always with the drawback I have mentioned) in conducing to the safety and regularity of our work."

It is hardly, then, the apparatus connected with the block system which Sir Edward Watkin would propose to put into the fire. Is it the locking apparatus that he would wish to commit to the flames? Speaking at the South-Eastern meeting, he says, it will be observed, "we got no hints from the board of trade." Speaking at the Metropolitan meeting, in regard to a collision under the block system, he attributes it to the Board of Trade meddling, as I shall presently show. But, in reality, the same hints and the same meddling applied to both railways equally, excepting that there were additional hints in the case of the South-Eastern Railway, which may be quoted, both as opening up another interesting subject for discussion, and as showing the risk that an officer of the Board of Trade may incur even when invited and doing his best to assist a company presided over by a chairman, who, like Sir Edward Watkin, attributes accidents which arise from a mistake of his signalman to the Board of Trade. Some months before the Charing-Cross Railway was open for trafic, the author was asked by the South-Eastern Company to make a preliminary inspection of it, and to confer with the officers of that company as to the best mode of dealing with the signal and working arrangements, and he had, as he always has, great pleasure in being of any use in that respect. Besides the general arrangements, which were agreed upon without much difficulty, an important question arose, in regard to the working of the block system. It was proposed by the company to work the Charing-cross line by bells only, as other parts of the South-Eastern Railway were worked, without block instruments. But the author ventured to dissent from that proposal, and to express the opinion that, considering the importance of the line, and the nature of the traffic which it was likely to accommodate, it was absolutely necessary to provide visual as well as audible instruments, to give the signalmen, in fact, the advantage of a record before their eyes as to the conditions of each block-length—whether it was obstructed or whether it was clear—in place of trusting to their memories as to the last signal

which they received or transmitted on their bells or gongs. The author stated, in fact, that he would be unable otherwise to recommend the Board of Trade to sanction the opening of the line. The talented electrical superintendent of that company accordingly contrived and provided, before the opening of the line, the minaiture semaphore signals which are working in the cabins; and the safety of the line has been probably due in some respect to the "hint" on which the company thus acted. And this hint may further be supposed to have been considered valuable, inasmuch as the use of Mr. Walker's miniature semaphore has since been extended to all other portions of the South-Eastern Railway. But if any accident had occurred through the failure of, or in working those instruments, ti would, of course, have been open to the chairman to attribute it to Board of Trade meddling, as he did, publicly, the collision which occurred on the Metropolitan Railway, between the Gloucester-road and the Kensington High-street stations, on the 29th of August last. In that case a disabled train proceeding from the Mansion House Station to the Edgware-road Station came to a stand in a tunnel after passing Gloucester-road; and the signalman at the High-street Station, when an unusual length of time had elapsed since he received notice of it, asked on his speaking trumpet, "Is train coming?" to which the Gloucester-road signalman replied, "I have not received line clear for last train." The signalman at the High-street, fancying he must have forgotten to give "line clear," did so, and a second train was thus allowed to enter the block length before the first train had passed out of it. Sir Edward Watkin remarked upon this at the half-year meeting of the Metripolitan Railway on the 22d of January, 1874, as reported in the *Railway News* of the 24th of January:

"Now this accident, the first of the kind which has occurred, I think, during a period of twelve years' working, ought to be called—as many accidents out to be called—a Board of Trade accident."

And he proceeded to argue that because the Board of Trade recommended in their general list of recommendations—for it was not an absolute requirement—speaking instruments as well as block instruments in the cabins, and because the signalman had, in calling attention and replying on the speaking instruments, committed this error, therefore the accident was, as he put it, "the consequence of the Board of Trade meddling." There was, however, another recommendation—that record-books should be kept also in the cabins; and this had not, it appeared, been complied with in the Gloucester-road cabin. Whenever an accident occurs at any place where every precaution has been taken to avoid it—and such accidents must be expected occasionally to occur— and where all the requirements and recommendations of the Board of Trade have been complied with, it will of course be open to any chairman of a company, so disposed, to attribute such accident to Board of Trade meddling, and to call it a Board of Trade accident. But in this particular instance the signal-man might have committed the mistake in question without speaking instruments at all. The recommendation with regard to the adoption of speaking instruments in addition to block instruments is contained in clause 7, under the heading of "Precautions Recommended in the Working of Railways," and is as follows:

"When a line is worked by telegraph, the telegraph huts should be commodious, and should be supplied with clocks with record-books, with a separate needle for signaling the trains on each line of rails, and with an extra needle for other necessary communications between the signalmen."

It was adopted because signalmen had been found to be making private signals to one another on their block instruments or their bells, "shaking each other up," as they termed it, by shaking the needles and so on. The recommendation has, in very many cases, not been complied with, and it will be an interesting subject for discussion whether and how far it should be acted on, as well as how far it may be considered desirable to depend upon bells alone without block instruments. Speaking instruments are, indeed, absolutely necessary in many cases, when it is considered requisite to afford information from distant stations of the running of fast non-stopping trains —whether they are keeping time, or whether and how much they are behind time. They are required in other cases for the transmission of messages on the company's service in regard to the working of the line in various respects. In the absence of them, the block regulations of some companies prescribe codes of signals

by beats on the telegraph bells; and the number of beats required for such purposes mount up, as already stated, to 14 or 15. It is an important question to consider whether the signalmen may not make mistakes in counting so many beate on the bells more easily than in the use of speaking instruments. Sir Edward Watkin's proposal in the same speech was to send a man in place of using a speaking instrument, and was thus expressed:

"The idea of the Board of Trade, no doubt, was this: that if anything took place in the way of blocking, the signalman should be able to ascertain what it was, instead of pursuing the old-fashioned plan, that when there was a block somebody should be sent to see what it was."

But no man would in this have been sent running from the Gloucester-road signal cabin to the High-street signal cabin, even if there had been no speaking instruments in the cabins; and at all events the Board of Trade have never made any objection to Sir Edward Watkin's employing men in that capacity if he thinks proper, and finds it compatible with the working of the traffic on the Metropolitan Railway to do so. It is the more necessary to make the above observations because Mr. Forbes, the chairman of the Metropolitan District Railway, is reported to have echoed in some degree the sentiments of Sir Edward Watkin in regard to the accident on their joint line. According to the *Railway Times* of the 14th of February, 1874, Mr. Forbes is reported to have said, at the half-yearly meeting on the previous Tuesday, of the Metropolitan District Railway:

"The item of compensation had been 5000*l.* extra in the half-year, with which they had really nothing to do. The accident was caused by one Metropolitan train running into another Metropolitan train, and they had to pay one-third of the cost under the agreement with that company. He complained that under the direction of the Board of Trade they were obliged to use apparatus that had caused accidents and had entailed a loss of 18,000*l.* in damages, which he thought very hard indeed.

It would be interesting to learn from the general manager of the Metropolitan and the manager of the District Railway, whether now, after the experience of that accident, they are prepared to remove the speaking instruments from all the signal cabins, and whether they could carry on the working of the line without them. Unless they can come forward and tell us that they are prepared to adopt this meas ure—which. if they consider it expedient, there is nothing to prevent them from doing—it must be admitted that the remarks of Sir Edward Watkin and Mr. Forbes on the subject were more ingenius than ingenuous; and the author contends that they were, in any case, in the highest degree unjustifiable.

Fully to expose the injustice and the nature of the accusation thus made by Sir Edward Watkin and Mr. Forbes against the Board of Trade for causing this accident by meddling, because one of their recommendations is that there shall be "an extra needle for other necessary communications between the signalmen," it is right, however, further to point out that the printed regulations for signalmen on the Metropolitan Railway provide for the use of speaking instruments, two in number at terminal, and three in number at intermediate stations, that there are six in the cabin in which the mistake was made, and that the signalmen are directed to use these speaking instruments when the disc instruments are out of order, or the bells fail to ring.

The following are the regulations referred to, extracted from "The General Rules and Regulations to be observed by the officers and servants employed by the Metropolitan Railway Company:

"118. The station at each end of the line is provided with two train signalling instruments, one for the up-train service and one for the down-train service, and a telegraph bell instrument; two speaking instruments are also provided, one to communicate only with the next station, and the other instrument for commun cation with all stations.

"119. The intermediate stations and junctions are each provided with four train signalling instruments, one for up-trains and one for down-trains in one direction, and one for up-trains, and one for down-trains in the opposite direction, with two bell instruments; three speaking instruments are also supplied, one for use to and from the station on either side, and the through instrument, by which each station is in communication with every other.

"131. Should the disc instrument be out of order, or the bells fail to ring, the speaking instrument must be used for the purpose of signalling the trains."

And the following is a regulation for signalmen, to a similar effect, from the printed book of rules for the Metropolitan District Railway:

"90. Each station has an independent speaking instrument to the next station on the either side. There is also a through speaking instrument, by which each station is in communication with every other."

The rule-books of these two companies thus provide for speaking instruments in the cabins, in excess of the Board of Trade recommendation; and it is due to the companies to suppose that they do not supply more instruments than they find in practice to be necessary. But it is anything but justifiable in the chairman to represent that an accident occuring in the use of instruments provided for their own purposes has resulted from their being forced to obey a Board of Trade recommendation, contrary to their own convictions; and especially when there are signal cabins on other lines where the recommendation in question is not complied with at all. The railway companies have not, indeed, always been in the habit of so implicitly carrying out the recommendations made to them by the Board of Trade as might be inferred from the accusation referred to.

Mr. Forbes, also at the half-yearly meeting of the London, Chatham, and Dover Railway Company—as reported in the *Railway Times* of the 14th of February, 1874, "protested against the duplicate management which was being instituted by the Board of Trade, for it was this it amounted to, and the department was placing more faith in machinery than in men. This was really deteriorating the men, for they relaxed their watchfulness in the trust in machinery, and were trapped into a security which had led to two accidents on the line."

Mr. Forbes does not state what accidents he particularly refers to, or by what special machinery the men are trapped into security; and it is therefore impossible at present to reply in detail to his allegations; but if he will be more specific on these points it will add to the interest of the discussion, and his charge, shall be fairly met. Meanwhile, the author is quite ready to admit, and has often stated, that there may be a tendency in the block system to engender confidence in engine drivers, guards, and all connected with it, as regards the safety of these trains from collision; and that such confidence is justified by the results of its working. But while it is only natural that engine drivers should have less apprehension of obstruction from trains, it must be remembered that there are still public road crossings, occupation crossings, the liability to find plate-layers at work, or vehicles thrown from another line foul of that on which they are traveling, as well as other causes, requiring them to look out. The experience of block working hitherto has not justified the apprehension which has, at times, been expressed of greater danger being incurred, and more serious accidents being caused, as the result of undue confidence thus engendered. Instances may, it is true, be adduced of engine drivers running past signals, or of signalmen making mistakes, under the block system. But many more instances may be brought forward of similar causes of accident where the block system has not been in force. The great balance of actual experience, up to the present time, has shown that there is more risk of inattention, mistakes, or neglect on the part of officers and servants in railway working when they are constantly compelled to work with insufficient appliances and accommodation, and are thus trained, so to speak, to dangerous practices, than when they are provided with the means of carrying on their work in a safe and proper manner; and good discipline, which is, after all, and in any case, a most important element, can then better be maintained. And the memorial and opinions already referred to of the engine drivers on the North-Eastern and London, and North-Western Railways, are illustrations of the natural desire which these men must, more than any others feel to be afforded the means of carrying on their daily work under safe conditions, with sufficient warnings of obstructions, and ample means of obeying signals.

As an illustration of the necessity for block working combined with more accommodation for the conduct of traffic, and of working of railway traffic under difficulties, the author cannot do better than refer to the circumstances of a collision that occurred on the 13th of December last, near Bolton, on the Lancashire and Yorkshire Railway. On that occasion, a down passenger train from Manchester to Fleetwood overtook,

whilst running, and came into collision with, an empty wagon train, in a misty state of atmosphere, a mile and a quarter after leaving Bolton; and a portion of the wreck having been thrown upon the other—the up line—it was immediately afterwards run into by an up passenger train from Southport for Manchester. In this double collision, forty-two passengers and six servants of the company were injured or shaken. There are two signal cabins, 194 yards apart, called the Bullfield upper and lower cabins, on the further side of the Bullfield tunnel from Bolton; and the signalmen in those cabins, who had, as usual, exhibited caution signals only from their hand-lamps, were dismissed from the company's service for not obeying the regulations, which required them to show a danger signal for five minutes and a caution signal for five minutes longer after the passage of the empty wagon train to any following down passenger or other train. But it turned out on inquiry, that it had not been the practice at those cabins, at all events for eight years, to obey those regulations—that the signalmen did just what they were in the habit of doing, and what other signalmen working in those cabins would have done; and that the traffic could not have been carried on in conformity with such regulations. One of the signalmen further pointed out that he could not be expected to keep the trains five minutes apart when they timed to start from Bolton within two and three minutes of one another. A relieving signalmen, not concerned in the accident, stated that he would have worked in the same manner, and himself have been dismissed from the service of the company, if the accident had happened an hour later; and he further stated that when he left his cabin to give his evidence, there were five engines—which turned out on enumeration to be six—on one main line, and three on the other main line, of which one was shunting in and out of the sidings at each side, and the others were waiting to shunt or to pass. The engine-driver of the passenger train, who had complained before leaving Bolton of the empty wagon train having been sent away in front of him, was told in reply that it could not be helped. Now there were no "new-fangled things," at these cabins. They were stated to be twenty years old, with such apparatus as they contained; and there was certainly nothing in their appearance to lead to a contrary opinion. The author ventured to think that less confusion and more simplicity in dealing with the traffic might be obtained by the addition of extra lines and sidings, and by the construction of improved cabins with modern apparatus in connection with them, and also by the extension of the block system (at present in force for the Bullfield tunnel only) to the portion of the line on which the collision occurred. The caution, the presence of mind, and the self reliance of the officers and servants of the company must, certainly, have been developed to the utmost in the working of this traffic; but not with with a satisfactory result, either to the passengers and servants of the company who were injured, or to the two signalmen—of good previous character—who lost their situations for doing their duty to the best of their power, as they had been trained to do it, as they had always done it, and as they were compelled to do it. The neglect of fallible servants will, no doubt, be considered by some to be a cause ot this accident; but it is not essential to railway working that frail human nature should be employed under such conditions; and the author would commend this case—one of the more recent which it had been his duty to investigate—to the serious considerations of those who, in opposing what are called "modern requirements" on railways, like Mr. Harrison and Sir Edward Watkin, are inclined to lay too much stress upon human frailty as the cause of accident, to decry the means and appliances by which that element of constant risk may be in a great measure neutralized, and to leave out of consideration the difficulties—the disadvantages, and the defective or insufficient arrangements under which the officers and servants of railway companies are frequently compelled to work. The opponents of modern improvements, which are thus designated as "new fangled things," are, in fact, not now found so much amongst the officers and men who have the practical working of them. Such officers and men, on finding out the value of them for their own protection, and for real simplicity and safety in working the traffic, are only too glad to obtain them, and are only anxious that their operation should be extended. The opposition to them comes mainly from certain chairmen and general managers of railways and others whose practical experience was gained in former years before many of the improvements now so suc-

cessfully employed were available, and under different circumstances of traffic; and from gentlemen such as the President of the Institution of Civil Engineers, who having some time since retired, as he tells us in his address, from the active work of railways, has not yet realized the benefits which such improvements confer. Many who were once opponents have now become firm believers, and, sooner or later, the true difference in such matters between simplicity in construction and simplicity in working will, the author believes, be all but universally understood and admitted.

Since the above was written, another eminent and practical railway chairman has made use of arguments and expressions which can hardly, in such a paper, be passed over without notice. Sir Daniel Gooch is reported in the *Railway Times* to have said, at the last half-yearly meeting of the Great Western Railway Company, on the 4th of March:

"We complain of the mechanical arrangements and contrivances, and different things that are forced upon railways contrary to the opinion of the railway engineers and officers who are responsible for working the railways, and who have had experience to enable them to judge of the efficiency or otherwies of these contrivances. Therefore we say, and say it very strongly, that these contrivances of the Board of Trade, to the extent to which they are forced upon us, are increasing the danger of our railways."

And again:

"Undoubtedly our mechanical contrivances are very ingenius and clever, but they are not equal to the mechanical contrivances and appliances provided by a higher power; therefore I have much more confidence in a well-trained pointsman at his post than in any mechanical appliances designed to take his place."

These quotations would seem to convey the ideas: 1. That railway companies ought to abolish locking apparatus and trust to Providence; 2. That the Board of Trade is seeking to supplant well-trained pointsmen, and to emply mechanical contrivances and appliances in place of them; 3. That the danger of railway working is being increased by a number of things—though it is not stated what things—which the Board of Trade is forcing upon railway companies. Sir Daniel Gooch no doubt honestly feels what he so pithily expresses; but he cerainly exhibits an extraordinary misapprehension of the principles by which all the action of the Board of Trade has been guided. And, indeed Mr. Harrison made a complaint in the opposite direction, namely, that the requirements of the Board of Trade would necessitate the employment of a much greater number of signalmen, and thus lead to increase risk. Placing side by side the allegations of the four eminent gentlemen who are the chief complainants, it will be observed Sir Edward Watkin cuses the Board of Trade of two heresies—one, in considering the men infallible and the other in expecting too much from machinery; Mr. Forbes says that the Board of Trade mistake is in trusting to machinery rather than to men; Sir Daniel Gooch prefers to trust in well-trained pointsmen, which he looks upon as the better contrivances of a higher power; and Mr. Harrison complains—with special reference to the block system—that too many of these men are required. The truth of the matter is that the Board of Trade desires, not only to see well-trained signalmen employed, but also that they shall be provided with apparatus that shall enable them to work with the utmost possible simplicity, and shall neutralize as far as possible the mistakes that otherwise the best of men are liable—nay, are almost certain, sooner or later, in the course of years of working to commit; and wishes, further, to see their numbers increased only so far as is necessary for the proper performance of their duties, for affording due warning to the engine drivers, and for enabling the traffic to be worked in the simplest, best, and safest manner.

But the present is an admirable opportunity for these, or any other gentlemen, to come forward, and to state specifically what mechanical contrivances ought, as they think to be dispensed with, and what are in their opinion admissible. If the Board of Trade is proceeding on a wrong basis, in whole or in part, let them point out precisely what are its errors. The only object is to increase the safety and efficiency of railway working; and that object may, apparently, best be secured by more simplicity and less confusion in working, on the principles stated in the present paper. There has been ample experience as to the causes by which railway accidents have been produced, as to the defects which they have disclosed in construction and working, and as to the remedies by which they may be and have been avoided. The author has

labored anxiously and earnestly, by analysing from year to year the results of that experience, to afford the best means of judging—to any one who will take the trouble to study those results—not of the working of any one line, but of all the railways in the United Kingdom; and he will feel deeply grateful to any one who will correct him in any of the conclusions at which he has arrived, or point out to him any other mode by which the safety and efficiency of railway working may be better secured. Under no system can perfect safety be obtained—as he is too well aware—but confidence in a higher power, as it is expressed by Sir Daniel Gooch, can only with propriety be entertained after all reasonably means have been exhausted.

To sum up the whole case, it is necessary, in railway working, to deal with men and mechanism. Men are fallible, and mechanism may fail. The complications of railway construction and traffic have increased enormously, and are still increasing. At some points the lines, the sidings, and the crossings are so numerous, and the traffic is so constant, that the employment of the best means and appliances is unavoidable. In other localities, of severe gradients or obstructed view, or when greater danger is otherwise incurred, similar means and appliances are also indispensable. These points and localities become more and more numerous, and ample experience has now been obtained as to the most efficient modes of working. The result of that experience has plainly demonstrated that mistakes and accidents may best be avoided, and efficiency of working may best be obtained: 1. By judicious selection, and careful training of the men employed, and especially—in a safety point of view—of engine drivers and signalmen. 2. By providing those men with reasonable and necessary apparatus and accommodation for the proper performance of their duties. 3. By maintaining good discipline amongst them, which is only feasible when proper means and accommodation are provided, when proper modes of working are adopted, and when it is possible for them to carry out in practice the rules and regulations furnished for their guidance.

These three desiderata include the provision of fixed signals in sufficient number to enable the signalmen to afford due warning in each case in which warning is required to the engine drivers, and to enable the engine drivers clearly to understand the warnings so given to them. They include the supply of locking and other apparatus, which has been proved to act efficiently in preventing or neutralizing the mistakes, in the working of points and signals, which the best of men are otherwise, sooner or later, almost certain to commit. They include the addition of sufficient lines and sidings to enable the traffic to be properly worked—without goods or mineral trains constantly obstructing the passenger lines—without the main lines being blocked when fast through trains are due or may be expected—without excessive delay to slow or goods trains in waiting for fast or passenger train to pass—without stopping trains being shunted from one main line to another, to allow fast trains to pass them—without habitual unpunctuality. They include the necessary apparatus for enabling intervals of space to be preserved between running trains, and the proper arrangement and working of such apparatus, with the careful adaptation of it to local circumstances. They include the provision of ample retarding power in the trains, applicable at the will of the engine driver, to enable him to obey the signals which he receives, and to bring his train to a stand within a reasonable distance. They include, in fine, all those things which contribute to simplicity, and which tend to the avoidance of that great cause of extravagance, inefficiency and danger—confusion in railway working.

COMPOUND v. SINGLE CYLINDER.

From the "English Mechanic."

The superior economy of fuel in the ordinary form of the compound marine engine is generally considered as a fact so thoroughly establishd that many regard a man who has a contrary opinion as one ignorant of what has been accomplished. But the heretic finds comfort in knowing that there are men of very superior minds to whom these heretical opinions are orthordox.

Any one who has doubts, and wishes to investigate the matter will be rather disheartened by a few reflections which will be naturally suggested :—e.g., if the two principles are to be compared the conditions of the trial are such as to render the search for reliable data discouraging in the last degree. Suppose we were fortunate enough to find two ships of exactly the same build, engined, the one with compound and the other with single cylinder engines, the common parts of which being exactly alike, using the same steam pressure and ratio of expansion, the ships fitted with the same propellers and boilers of equal evaporative powers. Having found such ships, how are the trials to be obtained ? They must be conducted by good theoretical, as well practical, men —such as will not in the majority of cases, be found in charge, and the trials to be valuable must extend over very lengthened periods.

For myself, I know of no single trial which will satisfy these conditions.

All that remains is to reason as we best can upon what facts and information we can obtain.

In the first place, then, my argument demands that I must say a few words respecting the two kinds of compound marine-engines, viz. The Hornblower or Woolf, which, during expansion, exhausts directly from one cylinder into the other; and the common form exhausting from the small cylinder into a receiver. With respect to the first the Woolf, I think few will say that in economy of fuel it is not, at least, *equal* to the Receiver principle. But as even this may be questioned I shall first state that Messrs. Randolf and Elder's first patent (specification No. 177, 1853) was for improvments in the Woolf form, the cranks being placed opposite each other ; and that the Receiver was first introduced, *as a necessary evil*, for the more convenient handling of the engines, the cranks being 90° apart;—and then I may call attention to the fact that some of our most successful engines in point of economy of fuel are those having no receiver ; or those the more nearly resembling Woolf's principle.

In support of this I beg to refer to the evidence of Mr. Wright, the Admiralty Superintendent of Machinery, before the Commission on Designs for Ships of War 17th May, 1873: —" 3,536. Question : Supposing you did away with the jacket, would you still keep the receiver itself ? Answer : I think on the whole we are in a measure obliged to do so at present, for convenience in handling the engines. In point of economy, I presume it would be better if the steam could be sent in direct from one cylinder to the other." Again, the line of steamers known as " Holt's Line" are looked upon in point of economy second to none, and those engines are, in fact, Woolf's principle. The performance of the *Arequipa*, which in economy heads a list showing the average consumption of coal by steamships with compound engines in long sea voyages; the consumption is 1.7lb. per I. H. P. per hour, and the engines are by Randolf and Elder (Woolf). See " Proceedings of the Institution of Mechanical Engineers," July, 1872. Liverpool Meeting, part I., p. 158. Now, if it is granted, as I think it must be that compound engines of the Hornblower or Woolf type are as economical as the common marine engine using a rereceiver, an important axiom is admitted ; and as I am dealing with the question of economy of fuel alone, it immediately follows that I can compare the economocal performance of the compound with the single cylinder Cornish engine, and, by so doing, decide the respective merits of the compound and single cylinder marine principles. If this mode of reasoning is fair, I at once get rid of all uncertainty and dfficulties, and can proceed with my argument upon data which is undeniable.

The foundation of this data is the Cornish Engine Reports, which commenced in the early part of Watt's career, and are at this moment in progress. These reports show during the whole of this period the duty in actual foot pounds of the engines reported; and the perfection of the Cornish engine is chiefly due to the emulation created by them, not only in the proprieters of the mines, but even in the firemen and boys.

Armstrong, in his treatise upon boilers, has questioned the accuracy of them, but according to Pole, the injustice of this attack is now generally acknowledged. Wickstead, in 1835, visited Cornwall to inspect the engines there. An account of his visit is given in his work, and in the Transactions of the Institution of Civil Engineers. " He inspected several en-

gines, and the result of his examination was the perfect conviction of the accuracy of the reports given."

No person could possibly render more reliable information upon the subject than the reporters themselves, and it is from Lean's Historical Statement of the Steam Engine in Cornwall (written by a man who for many years acted in that capacity), I shall make the following extracts :

In the latter part of 1814 Woolf's engine was first introduced into Cornwall, at Wheal Abraham, and in October of that year, it was first reported, its duty being 34 millions. Soon after a defect was discovered, and the duty was advanced to 52·3 millions.

In 1816 Jeffree and Gribble erected a new single cylinder engine at Dolcoath which did 40 millions. Still Woolf's engines maintained the first place, the duty performed by that at Wheal Abraham was 56·9 millions.

In 1820 Woolf's engines with the double cylinders, owing to the difficulty of keeping them in repair, had fallen to the average of the best simple engines, *and after this period began to be disused in the mines.* Here it must not be forgotten that Woolf had a reputation for superior excellence of workmanship. In December, 1827, an important trial of Woolf's principle took place, at Wheal Fortune. The trial lasted 26 hours 30 minutes : duty 63,663,473. The report is signed by nine persons. Early in 1828 Woolf's engines at Consolidated Mines head the list with a duty 93·7 millions. The engine at Wheal Towan, by Gorse, comes next : duty 60 millions. Another trial in the same year of engine by Gorse, at Wheal Fortune (boiler pressure 40lb.), duty 87,209,662. The report is signed by Sims and nine others.

It is well to note that these trials were conducted by men of opposite interests, who questioned the accuracy of the reports : here the engine is by Gorse, and Sims conducts the trial, and signs the report.

The following extract I have made from the Report for 1828. I have selected a few of the best.

Wheal Towan	Gorse	87	mills.
" Hope		7.48	"
Consols	Woolf	67.6	"
Birmer Downs	Griger & Thomas,	63.5	"
Consols	Woolf	61.7	"

In 1835 a trial of Austin's steam-engine of 80in. cylinder, at the Fowley Consols and Lanescot Mines, (Oct. 22-23, 1835), with steam from 36½ to 45lb., gave a duty of 125,095,713lb. with one bushel of coals of 94lb. The trial lasted 24 hours and 27 mins. This was a very carefully conducted trial, and was well authenticated by many important witnesses whose names are appended.

In the same year I find the following duty recorded :—

	Engine	Duty
Consolidated Mines	Woolf's	55,776,172
Wheal Bor	"	47,541,497
Consolidated Mines	Taylor's	71,281,509
"	Davy's	76,128,086
"	Shear's	61,108,450
Wheal, Darlington		75,133,433

The above-mentioned single cylinder engines are only a portion of those performing a higher duty than Woolf's, and have not been selected by me.

In 1836 Wheal Darlington engine heads the list with 94·4 millions; Woolf's engines are not given, so that their duty may be considered under 60 millions ; it being the practice to expunge engines of low duty from the reports, in order that the average duty might not suffer ; for a low average duty, it was supposed, would have an injurious effect.

From the " Journal of the Royal Institution of Cornwall," Vol. XIII., 1872, we learn that the—"The system of combined cylinders modified by placing one above the other, and admitting steam above the smaller and upper, and allowing it to expand thence beneath the larger and lower piston, was introduced for a third time at Carn Brea and great S. George, by Jas. Sims ; but notwithstanding the high duty of 88 to 100 millions was reported this form of engine again failed to secure favor, and its use has been discontinued."

In addition to this I have learned from Cornwall, within the last few months, that no double cylinder engines are now reported in the county, and that several combined cylinder engines have been replaced by single engines. There is no question about the object of Woolf's Patent, viz, to introduce high steam pressures; and it appears from what I learn perfectly certain that he often used much higher pressure than those now common in Cornwall, and yet with his superior work and steam-pressures he never obtained so high

a duty as that exhibited by the single cylinder system, with a steam-pressure varying between 30 and 40lb. above the atmosphere!

This is an argument complete in itself, and will, if honestly considered, I am sure, be thought a sufficient excuse for thinking that there are good grounds for at least *suspecting* the much talked-of superior economy of the compound marine engine.

But we can go further than this with the argument! In the "Encyclopædia Britannica" for 1810, under article "Steam Engine," will be found a calculation either by Watt himself or Dr. Robison under the eye of Watt, showing that no possible advantage could be obtained from the use of Hornblower's engine, and bearing in mind that this engine was constructed to work at the steam pressures then in use (Woolf's being the same principle adapted for the use of higher pressures) it will be at once conceded that the proof given by Watt, or Dr. Robison, is that when steam of the same pressure is used the compound has no superiority over the single cylinder; indeed this much will be found in the following transcript:—

"We have done service to the public in showing that this engine, so costly and so difficult in its construction, is no way superior in power to Mr. Watt's simple method of stopping the steam. It is even inferior, because there must be a condensation in the communicating passages."

And turning from the Pumping Engine to the marine type, we find that where the steam has been at the same pressure, the economy has been the same: take the trial of the *Swinger's* and *Gohawk*, see the *Times* of May, 1872.

I have now said enough, I trust, to show that if the compound marine engine is superior to the single cylinder when using the same steam pressure and ratio of expansion that *the superiority does not lie in the economy of fuel*; but if space is allowed me I should like to go a little further, and to say a few words upon this question. Is it necessary to use steam of so high a pressure as 60lb.? for although I certainly think that, if proper regard be paid to the construction of the engine, and by using a fly-wheel, the single cylinder is as good for marine purposes with high pressure as the compound; yet there is this consideration; A compound engine, to effect a high rate of expansion, may be the cheaper machine of the two, for in it no expansion gear is considered necessary, but in the single cylinder a double expansion gear is required, and in addition, perhaps a fly-wheel. But suppose that for ordinary merchant ships one cylinder only with a fly-wheel were proved to work very well, how would the comparisons between the two principles stand then? There can be no question about the cost and economy of space being greatly in favour of the simple type. And why cannot this be done? We know that the Holt Line of steamers use engines in which the two cylinders work upon a single crank, and I have been personally informed that those engines are handled with the greatest ease. Land engines are generally on this plan and they are stopped and started in comparison, much oftener than the engines at sea.

But it is a point worthy of careful consideration whether steam of a higher boiler pressure than 35lb. is necessary to effect the same economy as that of 60lb. In the Cornish engines we have seen that the greatest duty was given by that (35lb.) mean. Cramp ton in experiments conducted by him, where the actual duty was obtained, found that nothing was gained by working over that pressure. Mr. Hawksley's opinion also confirms that view. And if it is a fact that a boiler pressure of 30lb. or 35lb. above the atmosphere will give the greatest economy, the argument for the use of one cylinder only is vastly strengthened and it is to be regretted that no really scientific experiments have been tried to decide the question, which might easily be done by taking a compound marine engine and an engine of a single cylinder of the same power, with the common parts exactly similar, arranged to work from the same boiler; to use the same condenser, and to work the same pump or friction brake—then by trying them, say for a week each, alternately, until a definite result, both as to economy and equability of motion were obtained. And I cannot close without saying that I consider it a monstrous disgrace to a nation like England that such experiments have not been made, instead of wasting time in inquiries from which no definite good seems to accrue.

THE FREEBOARD OF MERCHANT SHIPS.

From "Engineering."

The question of the freeboard of merchant vessels, which has for many years been more or less under discussion to very little purpose, has, within the past twelve months or so, been the subject of renewed interest, and has given rise to vigorous thought and action, which have together made a decided and permanent advance towards a solution of the question. The powerful pressure brought to bear upon the legislature to fix by law a hard and fast load line for all vessels has done much good in proving, by the exhaustive examination of the case which ensued, that it would be impossible to fix a hard and fast maximum load line without doing one of two things, viz., to encourage and countenance overloading by law, or to seriously hamper and interfere with the safe carrying trade of the world, with the prospect of placing English shipowners at a ruinous disadvantage in some trades, compared with foreigners.

It is almost obvious, but it has required a vast amount of argument to prove it to some, that a vessel running across the Channel in the middle of summer, could carry a certain cargo with less fear of foundering, than she could cross the Atlantic in the middle of winter with a much lighter cargo. But if the winter Atlantic load line be fixed as the legal maximum on all voyages, it would be seriously, unjustly, and unnecessarily restricting the vessels' carrying power on the short summer voyage, to an extent which would perhaps destroy all hope of a profit on such voyages, with foreign ships in competition. On the other hand, if the maximum safe load line for a summer voyage across the English Channel be regarded as the legal maximum load line for any voyage, it would inevitably lead to this load line being adopted for other voyages, for which it would be positively dangerous. Between these two extremes there is for every ship an endless number of safe and proper load lines, each depending upon the particular voyage, the season of the year, and the nature of the cargo and storage. Hence the difficulty and almost impossibility of fixing by law any hard and fast load line, even supposing the difficulty of framing a rule which would apply with equal justice to all vessels to be definitely overcome. Mr. Plimsoll's original idea of fixing the load line by act of Parliament must therefore, be abandoned. There can be very little doubt that the Royal Commission, after all the evidence they have heard on the point, will go dead against it. And as Mr. Plimsoll himself has recently found a substitute for his previous load line, we may expect that we have heard pretty nearly the last of a "hard and fast" load line for a long time to come. Yet no one acquainted with the subject can doubt that overloading exists to a fearful extent in the mercantile marine, or that a very large proportion of losses is due to this cause alone. We do not here refer especially to the flagrant cases, which are for the most part being picked up, or indirectly prevented by the vigilance of the Board of Trade. What we refer to more particularly when we speak of the dangers of overloading, is the great temptation there is, even among respectable shipowners, to increase imperceptibly the amount of cargo, until the practice becomes countenanced, and in the end prevails, of loading vessels, and especially steamers, deeper than they should be loaded. Many vessels are constantly running in this condition, while everybody connected with them has got to believe that they are in perfect trim. They have perhaps met heavy weather on more than one occasion, and behaved well. This confirms the practice, but a time comes at last which finds out the weak point, the weather is called extraordinary, and the vessel goes to the bottom. This is not criminal overloading, but the result of ignorance on the one hand owing to the absence of any recognized standard of reference as to safe loading, and on the other the effect of keen competition and a desire to make money as fast or faster than others in the same line of business.

Among the various proposals for lessening these dangers the most simple and practicable are the following, namely:

1. To place on every vessel amidships

a scale of feet to mark the freeboard in somewhat the same way as it is now insisted upon for marking the draught of water forward and aft.

2. To place on the side of every vessel amidships a mark or marks showing the height at which a certain proportion of the internal capacity would be cut off and be above water if the vessels were loaded down to those marks.

3. To determine upon a scale of freeboard which would apply equally to the different types of vessels, and represent what would be a fair load line for the vessels upon ordinary voyages. To recognize this load line, not as a hard and fast load line, but simply as one for guidance, and to throw the onus upon the shipowner in the event of his loading beyond this line; of showing that the circumstances attending his doing so, such as the nature of the cargo and the voyage, the season of the year, and the construction of his vessel, were such as justified him in taking in more cargo than would otherwise have been deemed safe loading.

The first proposal is the simplest of the three, and the reasons to be urged in favor of a compulsory lettering of the freeboard amidships are at least as strong as any that can be urged for making every vessel have the draught of water marked on the bow and stern. It would enable the officers of the Board of Trade, or any others interested in the loading of the vessel, to read off the amount of freeboard as easily as they can now take the draught of water, and the two sets of figures in themselves would enable a rough idea to be formed on the spot as to the extent of the loading. This simple action might form a check upon overloading, but it is only likely to do so indirectly by acting upon the fears of the owners as to some possible contingency. It would cause a certain restraint, but it would unfortunately act least powerfully on the more reckless, and would cause uneasiness and uncertainty in the minds of those only who are most anxious to do only what is safe and right. There are other objections to this proposal, which all apply to the proposal No. 2, and they will be considered under that head.

The second proposal, which is generally known as Mr. Rundell's, is to mark the percentages of spare buoyancy amidships, or more correctly speaking to mark the percentages of internal capacity which would be above water at certain draughts of water. If we were dealing with vessels all of the same type, or approximately so, this plan would doubtless meet with general approval, because then a mark showing say 25 or 30 per cent. of spare buoyancy would form a fair general guide for loading. It would have this merit over merely marking the freeboard by feet and inches, that it would place full and fine vessels upon an equal footing. There would of course be the difficulty between ships of different sizes, because universal experience is in favor of allowing a larger proportionate amount of freeboard or spare buoyancy in large vessels than in little ones, so that there would probably have to be a sliding scale of percentages somewhat similar to the present sliding scale of inches clear side per foot depth of hold known as the Liverpool rule for freeboard. And here we come immediately to the chief obstacle to Mr. Rundell's proposal. He has suggested the marking on all sailing ships the height at which one-fourth of the internal capacity or 25 per cent. would be cut off. This would be pretty near the load line for small ships, but would be far too deep for large ones, and would be a direct encouragement to large vessels to load down towards it. Would it not, therefore, when we are placing a percentage marked on the side of a vessel, be better to put one which would indicate the depth to which the vessel could fairly be supposed to load than to a mark likely to mislead.

When we come to steamers, with all their varieties of type, proportions, and superstructures, the objections to placing a uniform fixed percentage mark on all of them becomes far more serious than in sailing ships. In the first place, there, is a difficulty in many vessels of knowing to which deck the spare buoyancy should be estimated. There are, in addition to the complete three-decked steamers afloat, many having spar decks, or awning decks, and others which are really spar-decked vessels, but without the title. Some of these should, in all fairness, have the benefit of having their spare buoyancy estimated to the upper deck, while others should only be estimated to the main deck, and to discriminate between them, some standard as to

strength would have to be instituted, which would lead to endless difficulties, and open up the broad question of proportioning freeboard in relation to the structural strength. Mr. Martell, who has devoted much attention to this question, says, in his able paper "On Freeboard," read before the Institution of Naval Architects, and reprinted in *Engineering* May last, "Thus, in a flush-decked vessel having a surplus buoyancy of 27 per cent., by the erection of a raised quarter deck it would be reduced to 24½ per cent.; with the more perfect protection of a full poop, it would be reduced to 23¼ per cent.; with the entire main deck covered in with an awning deck, it would be reduced to 19 per cent.; with a spar deck lightly constructed as described (having only half the frames extended to the spar deck), it would be less by 13½ per cent.; and in spar-decked vessels of various degrees of additional strength above the main deck, the surplus displacement to the same deck would be reduced in relation to the nearer approach of the topsides to that of a three-decked ship."

Here, then, we may have in two ships of the same principal dimensions a difference of 13½ per cent. of spare buoyancy between the suitable load line for each type, owing to one having a light covering deck, and the other being without any means of carrying up the protection for her engine and other openings above the main deck.

To put the same percentage mark on all these vessels, whether it happens to come near the point to which they should be loaded or not, can scarcely be considered otherwise than going to a great deal of trouble to teach people how to load their ships, and shirking the main point on which they wish to be enlightened, viz., what would be a fair draught to load their vessels to.

It may be said that marking the freeboard in feet and inches equally shirks the difficulty of affording any guidance for loading, and that is quite true. But it does not pretend to do more than record the freeboard, whereas it would be impossible to go through the scientific process of obtaining a percentage of spare buoyancy without making people believe it was giving them a mark for their guidance in loading. It would be just the same if we decided to mark a freeboard on all vessels of three inches to the foot depth of hold. We should be indirectly countenancing a false standard of loading, although it might not be intended that all vessels should load to that depth.

The third proposal to which we have referred is that laid by Mr. Martell before the Royal Commission, and since embodied by him in his paper "On Freeboard," from which we have already quoted. Mr. Martell admits the impracticability of fixing a hard and fast load line to all vessels, irrespective of the nature of the voyage and cargo, but he maintains that for every vessel there is a certain load line which is as deep as she should go to for ordinary voyages, and this load line he has embodied in a series of Tables, which form beyond question the most valuable documents yet published on the loading of merchant ships. These Tables afford a ready means of arriving at the freeboard of any vessel from her registered dimensions of length, breadth, and depth, and her register tonnage under deck. They are based upon the principle of allowing a certain proportion of surplus buoyancy, but with this principle modified, and very properly so as we think, by additions to the freeboard on account of extreme proportions of length to beam. Mr. Martell takes the ground that if we interfere with loading to such an extent as to mark the sides of all ships, we should place the mark at what would be a a fair load line for ordinary ocean voyages. He contends against this being regarded as a hard and fast load line, and thinks the owner of the ship should be allowed to load beyond this line if he chose, but that in the event of a casualty he should be required to justify his having done so according to the circumstances of voyage and season.

It seems obvious that if the officers of the Board of Trade, or any other public officials, are to be held responsible for stopping overladen ships, they must have some rule to fall back upon, if it is simply for the purpose of conducing to uniformity of practice throughout the country. It is equally clear that if a hard and fast line is impossible, the next best thing is an average load line, suitable for ordinary voyages.

The elements necessary to be combined in a reference standard for loading are: first, simplicity of application; second, to be in accordance with the best experience

obtained with various types of vessels; and third, that it should be based upon sound principles, so as to secure general as well as individual accuracy, and avoid leading to the construction of ill-formed ships. These elements have been combined by Mr. Martell with very considerable success, and they will do much to secure at least a tacit recognition of the Tables. It can only be by continued application of the system that shipowners will learn its value, and this is a question of time. On the other hand, if it gains the confidence of the shipping community, it will soon become a standard of reference in the law courts and about the docks, and would have to be recognized by the Government officials and underwriters' officials who have to watch the depth to which vessels are loaded for their outward voyage.

To conclude, it would appear that the freeboard amid ships in feet and inches is almost a necessary preliminary step in any attempt to check overloading, but that it cannot be more than a mere step until it is accompanied by some standard of reference as to what is a fair load line, which, if we judge Mr. Martell's scale of freeboard rightly, has been well supplied by him. But it is probably better, on the whole, that his Tables should be allowed gradually to assert themselves, than that any official stamp should, at least yet, be placed upon them by the Board of Trade or by Lloyd's.

Of Mr. Rundell's proposal, we can only say that it would require active official interference and great labor to place his percentage marks on all ships with any degree of accuracy, which, in itself, is enough to prevent its adoption, and that when they were placed on vessels they would be more likely to prove misleading than to achieve the object sought by their author.

RIVER EMBANKMENTS.

From "The Engineer."

The permanent effect resulting from the embanking of the tidal or non-tidal portion of the river will in a great measure depend upon the precise object sought to be accomplished by the embankment. This object, or primary purpose, as it may be termed, is not the same in all cases, although to assume that it is, is not unreasonable. In one case the immediate point kept in view may be the preservation and protection of the banks and adjoining district, without any regard to the subsequent improvement or deterioration of the river itself. In another, the conditions may be reversed, and the improvement of the river considered as the chief feature in the undertaking, any benefit that may accrue to the riparian property being contingent. The third case, that in which the objects of the embankment are effected in their fullest and most legitimate manner, is when due regard is had to both the land and the river, and their mutual amelioration is the result of the project. Under the first category are included all embankments and walls erected solely for the reclamation of land, while the second embraces rather a peculiar class, affecting only the navigable channel of a river. These are known as training or low water walls, and are constructed for the purpose of causing a river to preserve a uniform permanent course. There are very few rivers which will in their natural state preserve the same channel for any length of time. This tendency to deviate from course to course, which is influenced more or less by the nature of the river bed, and the manner in which the stream is acted on by the wind and tide, causes a continual variation in the depth, and renders the maintenance of a navigable channel well nigh impossible. The effect of the training walls is to maintain the current constant, both in direction and strength, and of a uniform depth. Many of these walls, which have an average height of four feet above low-water level, have been constructed for the improvement of the Ribble and Tees. The recent opening of the Chelsea Embankment, extending on the Middlesex shore of the Thames from Battersea Bridge nearly to Chelsea suspension bridge, a distance of upwards of three-quarters of a mile, affords a favorable opportunity of adverting to the general scheme of the embanking of our metro-

politan river, and the possible effect that may result from the combined action of the embankments and the bridges. We may omit all consideration of the land which has been reclaimed, utilized and made a source of profit, both publicly and privately; neither shall we allude to the sanitary phase of the question, which is endowed with merit of an unquestionable character, so far as concerns the metropolitan portion, strictly speaking, of the river.

In the improvement of rivers, the removal of all obstacles and impediments to the flow of the tide or current is invariably regarded as the first step to be adopted. These impediments are of two kinds. They may consist either of objects placed in the open waterway of the stream, such as the piers of bridges for instance, or of others connected with the shore and projecting from it. Let us take the former, and consider what happens supposing the tide be running out. The water as it breasts the impediment to its flow, rises in front of it, and becomes piled up against it, thus creating an artificial head. The consequence is, that at and in the immediate vicinity of these obstructions the scour is increased, and a considerable quantity of material dredged or scooped out from the bed of the river. After passing the obstacle the head of water diminishes, the velocity of the stream is reduced, the solid matter held in suspension is deposited, and the periodical repetition of the same operation speedily leads to the formation of a shoal. The greater the breadth or face of the pier individually, or the greater the diminution of the waterway caused by all the piers collectively, the greater will be the obstruction to the flow of the stream, and the injurious consequences will be augmented in the same proportion. Arguing, therefore, on these grounds, we should naturally expect a shoal to be formed between any two bridges situated tolerably near each other over the same river. Experience has proved this to be the case with the Thames. A very formidable shoal existed between Westminster and Waterloo bridges, and to a great extent still exists. The removal of this was one of the improvements in connection with the river recommended many years ago by the first Commission who reported upon the project for embanking the Thames. An excellent idea of the practical piling up of the water against the piers of one of the Thames bridges may be gained from the deck of one of the river-steamers while passing under the arch of Vauxhall Bridge when the tide is running out strongly. The spectator will have a better idea of the great force of the current and the attendant scour if there happens to be a stiff head wind blowing, and the boat, as sometimes occurs, cannot shoot the bridge, but is compelled to put back and land him and the rest of the passengers at the Vauxhall pier down stream.

The same phenomena attend the existence of lateral obstructions, or those arising from the projection of objects into the waterway, from either one or both shores. Groins are of this description, and before the principles which govern the flow of rivers were well understood, were frequently adopted as measures calculated to improve them. But although sometimes locally beneficial, in the long run they are ruinous to the navigation of the stream. A very remarkable instance of the tendency of all obstructions to produce currents and distortion of the bed of a river occurred on the Tay.* A vessel of about 170 tons broke its tow line and grounded when there was some flood in the river. In the course of a few tides a regular pool was scoured out close to where the ship lay to a depth of ten feet. The gravel and other *débris* excavated by the force of the current, and amounting to about a thousand tons, was deposited in the form of a shoal or bank immediately below where the vessel lay, and rising to a height of five feet above low water. The formation of this shoal was evidently owing to the increased scour due to the artificial head of water raised by the obstruction, since the force of the current in its natural state was not sufficiently strong to act upon the bed of the river. The water-gate between Charing Cross and Waterloo bridges no doubt acts in the light of a lateral obstruction, and it is easy to trace at low water the formation of an incipient shoal, which will eventually assume more important proportions.

* "The Principles and Practice of Canal and River Engineering," by David Stevenson, F. R. S. E.

The general result of embanking any river is to contract the waterway, accelerate the velocity of the current, and consequently increase the scour. The tendency to scour out holes in some places and create shoals in another, is much enhanced when a tidal river, such as the Thames, for instance, is embanked for only a very small portion, comparatively speaking, of its entire length. Uniformity in the depth of water and in the velocity of the stream are the principal features which impart a navigable value to a river, and these it is impossible to retain, even if they once exist, in cases in which merely local improvements are effected. As an instance of the effect of embanking, dredging, and generally improving a river upon the bridges crossing it, we may quote from the authority already alluded to, the case of the Clyde. The Hutchison Bridge, which crossed the Clyde at the site of the new Albert Bridge, was erected in 1832. The masonry of the piers was laid at the level of seven feet below the bed of the Clyde, on a platform of timber supported by piles about eighteen feet in length. A section of the river at the site of the bridge was taken thirteen years after its erection, and it was found "that the level of the river had been lowered, in consequence of the improvements of the Clyde trustees, no less than eleven feet." The bridge was subsequently removed, and replaced by a new one. It is only fair to mention that even with the additional eleven feet scour the bridge might have remained safe, but the removal of a weir situated a short way above it rendered its removal indispensable. We are far from asserting that the case of the Thames is strictly analogous to that of the Clyde—although the velocity of the two rivers is about the same—but there can be no question that there is a tendency to a somewhat similar result with regard to the foundations of the bridges, especially those which have piers of masonry. It has been stated on good authority that shortly after the completion of that portion of the Embankment extending from Waterloo Bridge to that of Charing Cross, a large quantity of stone was pitched in round the pier of the former structure, which was nearest the Middlesex shore, with the object of forming an apron, and thus protecting the foundation from the action of the increased scour. If protection of this kind be really required now or at some future time for the foundations of any of the older bridges over the Thames, something more efficacious than loose stone must be employed to restore the original bed of the stream displaced by the scour. A steamboat was sunk in the Thames not long since by grounding on stones scoured out of their proper bed.

Without wishing to be alarmists, it is undoubtedly manifest to any one who has been in the regular habit of using steamboats for the last seven or eight years that a good deal more of the concrete in the Middlesex piers of Westminster Bridge is visible at low water than used to be the case. While we have every reason to be justly proud of our magnificent embankments, we ought not to shut our eyes to possible contingencies based upon the principle of hydraulic engineering. It is rare in mundane matters that good comes perfectly unalloyed with evil.

EASTERN ARTISANS.

From the "English Mechanic."

In offering some random observations on this subject I do not pretend to bring forward any new discovery in the way of mechanical construction from workmen who, from the long habit of using Nile mud only in their building operations, and of dabbing together various articles for domestic use of the same material, have consequently but a very crude notion of making anything either straight, square, or round. A few points, however, attracted my attention, that may bear curious comparison with the refined mode of working in other countries.

During a stay of several weeks in one place on the banks of the Nile, some half-dozen men brought down on the backs of donkeys a quantity of second-hand timber, of every variety of shape and dimension. One of the gang set to work on a large bag of old bent rusty nails of all sizes, and proceeded

to straighten them by laying them in a charcoal fire picking out the hottest as they came, with a pair of forceps, and flogging them out upon a block of granite. I soon saw that it was their intention to build a candjia or small trading boat, for sailing up the river, from the banks of which another man fetched a number of basket-loads of mud, and built up an arrangement for melting pitch, this was constructed of mud and bore a grotesque resemblance to a common laundry copper.

With a proper selection of crooked pieces of wood, and others made to suit by diligent adzeing, the framework of the vessel was quickly set up bottom uppermost, each rib as it was added being held in place by a temporary stretcher, aided beneath by props of mud. No mould-boards were used that I could perceive, nor reference made to any plan ; the model was arranged apparently by sight. The ribs, when all in place, presented a very fair outline of the usual Nile form of hull, that is, with the heaviest draught forward. As to the formation of these ribs, they had to cut their coat according to their varied stock of cloth, and no one matched the other in size and quality of timber. For example, there would be a square section of rib on one side, and the opposite one consisted of a round piece of wood, if it happened to suit in outline, and perhaps a long rib in another pair would be matched by several short bits, to make up its fellow, but these irregularities were distributed judiciously with regard to strength. Next came the planking, and in this they displayed their best skill. The only cutting tool employed was the "quadoom," a kind of short-handled adze, which they used very dexterously, trimming the edges of the planks to a pretty close fit where they came together. The back of the adze served as a hammer, and as in all their kit they only had the fragment of a saw, most of the planks were cross-cut by notching on each side, breaking off the piece and trimming the end with this universal tool. In order to economize wood (which is very scarce and dear in the country) the planks were not cut to match, or to waste, but laid on in all sizes and lengths. As soon as there was sufficient planking to hold the ribs together, the vessel, by dint of much heaving and shouting, was rolled over so as to lie in all positions, for convenience of working. The seams were caulked just the same as here, and when this rudely-constructed vessel was finished and payed, it was surprising how well and shapely she looked. Like all of her class, with cargo on board, the gunwale would be only just above the water level, therefore the most crazy planks were reserved for the barrier of wash-boards made water-tight, and fortified outside by a stately embankment of Nile mud, which in that country dries again very soon after it is wetted. Treenails were not used in the construction, for of these they seemed to have no idea ; in fact, they had no augers in the proper sense of term. If a hole of extra large size was required it was rimered out from a smaller one, with a cross-handled implement having a flat bit, shaped like the blade of an oyster-knife. The whole hull was fastened together by an enormous amount of nailing, and as this required a vast number of holes to be bored, these were made with an ease and celerity that would have put our best modern gimlets to shame, for much of the wood was acacia, and rather hard. The tools used were a kind of drill constructed as follows : a short stout piece of iron wire was driven into the end of a straight stick or staff, about one inch in diameter, and from twelve to eighteen inches long. An old ferrule or a few coils of wire prevented the ends from splitting. An inch of the other end of the staff was cut round as a shoulder, and the projecting piece whittled into a kind of knob, which was forced into a hole bored in a nut of the Doum palm. This knob must be rather larger than the entrance of the hole in the nut, and this having been scooped hollow when the staff is driven in, the nut, though quite loose, cannot fall off again. This served the same purpose as the handle of a joiner's center brace, and as the ivory-like substance of the nut is of an unctuous character, the rubbing parts do not chafe, but acquire a fine polish. This tool is used by grasping the nut as a handle, and rapidly rotating the staff by a drill-bow, consisting of the leaf stalk of the date palm, strung with a thong of hide. The various sizes of wire were quickly sharpened by merely hammering the end on a piece of iron and then rubbing them on a lump of grit-stone.

This leads to a description of the way in which the Turkish pipe-stems are bored. Curiosity prompted me to ascertain how this was done, for some of the stems are six feet long and drilled quite true and central throughout. The best sticks are said to come from the country near Constantinople, and are cut from a kind of dwarf cherry, spec-

ially cultivated for the purpose, and trained to grow perfectly straight; many are, however, obtained from oleander bushes in the valley of the Jordan. If the sticks are not quite straight when they reach the pipe-maker's hands he soaks them and dries them again under due pressure.

The workman squats before a log of wood driven into the ground or floor. In the top of the log there is an upright iron pin about an inch and a half long; a bobbin exactly resembling a common cotton-reel fits freely upon this pin. In the top of the bobbin is driven an iron-wire punch less in diameter than the intended bore of the pipe; the upper end of this wire is spread out by hammering, and made sharp like a brad-awl. A conical centre hole is dug out in the end of the stick to be drilled, this is set on the top of the sharp wire, which is rotated rapidly to and fro with a bow, the thong of which passes round the reel. For convenience, the work is usually begun with a short wire drill, and when all of this has entered, a longer piece with its attached reels, is substituted. The drill acting vertically, the fine borings fall directly out without clogging, or the necessity of withdrawing the drill till the work is completed. There is, however, one very important condition essential to the success of the operation. While the stick is being drilled, it must be held somewhat loosely in the hand so as to be continually shifting round; if this is not attended to, the bore is sure to run out of the centre of the stick. This may be exemplified by the operation of drilling up a brass wire for the purpose of forming a tube of small bore. If we attempt to accomplish this by fixing the wire in a vice, however carefully the drill is used, it will run out to one side before it has gone an inch deep. But if, on the other hand, the drill (formed of a piece of steel wire sufficiently long) is held as a fixture in the vice, and the wire to be drilled rotated on to it with a bow (the wire having a reel thrust on to it for that purpose) the bore will continue exactly in the centre of the wire. One end of this is pointed to run in the breast-plate and the other is marked with a centre punch, so as to run true on the drill point, this will come out at last precisely in the centre or point of the wire.

Disgressing from the question, in certain cases of moving the tool or the reverse in rotating work, it may be remarked, that in screwing wires, a far truer thread is obtained when the work is turned into the dies, and skilled gas-fitters well know that they get a thread free from drunkenness by fixing their die-stocks in the vice and screwing the gas-pipes into them.

Analogous to the pipe-stem boring, is the operation of the machine employed at the small-arms factory at Enfield, for drilling out the long hole in wooden gun-stocks for containing the ramrod. This is done with a long shell auger, but if this alone revolved the hole would never continue straight, but tend to follow the grain of the wood, as the slender bit is elastic and yielding. In order to prevent this, while the bit is rapidly revolving, the gun-stock also revolves more slowly in an opposite direction; this causes the hole to run true, however cross-grained the wood may be.

I once entered an armory in the East, where they were stocking and putting together common flint-lock horse-pistols, a brace of which every swaggering fellow likes to carry in his belt during an excursion. I, however, left in disgust, seeing that there was nothing to learn. They had no work-benches, but were all seated cross-legged on the ground, some using their naked feet to hold the work, a very common practice throughout the country, for when a man has gone all his life-time without shoes and stockings, his toes get properly exercised and developed, and become rather prehensile. At Cairo I once stopped to look into the stall of a man who had mounted a grind-stone, and gained his living by grinding edge-tools. There was no treadle fitted, he sat at the stone bicycle fashion, and turned the handle directly with his foot, hooking his great toe on to the iron crank-pin, round the end of which it had worn out a soft luxurious hollow, having an exquisite polish.

A number of fire-arms of the rudest construction are yet made in the East by the Arabs, but they all appeared to me to be very insufficient and harmless, and the old match-lock is still carried by some of the wandering tribes. During our travel through a part of Samaria, it was considered prudent to hire a Government escort, as the authorities then, to some extent, became responsible for any outrage on travellers. Accordingly we were provided with two "soldiers," mounted on pretty fleet horses, but the men had nothing, in dress or appearance, to denote a military calling or anything in their favor to distinguish.

them from the thieves against which they were sent to protect us. One of them was armed with a long spear only, the other had dangling at his side a most ridiculous abortion in the shape of a blunderbuss of native manufacture only eighteen inches in length. This suspended by a single sling from his neck, danced frantically about as he rode. The stock was too short to be held to the shoulder, and it would have to be fired pistol-fashion. The muzzle of the barrel was as large as an egg-cup, and the bore dwindled down to the size of a candle-socket at the breech. Irrespective of the moral effect its appearance might produce, I concluded that practically this must have been more a weapon of castigation than destruction, for if loaded with a charge of slugs, and fired into a group of men at a few yards distance, from its scattering proclivity, it would probably hit them all, and might perhaps break the skin and draw blood in a bare place without the risk of penetrating.

An Arab once undertook to guide us to a place where sport was to be had in shooting hares. He himself was armed with a native flint musket, tremendously long in the barrel; this was fastened to the woodwork of the stock by some dozen brass bands or ferrules, which he prided himself in keeping particularly bright. He soon shot a sitting hare, creeping up as close as possible. He asked us to reload his piece; this we were about to do with three drachms of English sporting powder. He said this would not do, as his gun would not kill unless it had six or eight drachms; this we gave him on his own responsibility, thinking it not unlikely that with our powder his frail piece would be blown to bits, as the substance of the barrel was scarcely larger at the breech than at the muzzle. When he fired again he neither hurt himself nor the game. An examination of the weapon explained the mystery, for the touch-hole was quite one quarter of an inch in diameter, thus acting as a kind of safety-valve, giving vent to more than half the force of the powder while the surplus was driving the charge. Barbarous as these weapons are, both in design and workmanship, yet the barrels of some of them are fine specimens of forging. I particularly remarked one piece; t was short carbine with silver bands to hold the barrel to the stock, which was also ornamented wi h silver. The barrel had not been bored, and was of a very curious pattern, not a spiral twist like ours, but an assemblage of fine bright fibres crossing in every direction. I was told that this was made at Damascus, and during my stay at that city I entered a smithy where arm were made.

The only fuel used was a fine quality of hard-wood charcoal. The bed of the forge was raised the same as here, but the curious feature was the back, which consisted of a slab of a light porous kind of fire-stone. Under this the blast entered, the tuyere appeared to me not to be a round aperture as with us, but was extended horizontally about two inches. Opposing the back there was a similar slab of fire-stone, which was set at various distances, according to the magnitude of the work to be heated. If this was small there was not more than an inch between the slabs for containing the ignited charcoal. The faces of the stone acquired a white heat, which was thus confined and reverberated on to the work, with but a small consumption of fuel. There were two single bellows of a circular form, connected by a rocking staff, so that while one of them was brought down the other was being raised and filled, thus giving a continuous blast. It might be supposed from this description, that the arrangement was rather a primitive and ineffective one, but the work done proved quite the contrary. The superiority of all ironwork forged with charcoal is well known, but if this were used in our form of forge with weighted bellows, it would be rapidly blown away. In the Damascus forge the pressure is obtained by the direct muscular force of the arm, so that the smith can regulate his blast by feeling, and instantly increase or diminish its force, or stop altogether, according to the state of the work; and the charcoal being confined in a narrow space between two walls of non-conducting fire-stone, the escape of heat as well as fuel is prevented.

New Nickel Mine.—Two rich veins of nickel ore have recently been discovered in the northern part of New Caledonia, the penal colony of France. Concessions have already been asked from the government for its exploration, which, however, cannot be well commenced before roads are opened to transport the products of the mine to an available harbor, at the sea-shore. As there are already mines of other metals on that large island in operation, there is a high expectation for material progress there.

ON VAULTING.*

By T. H. EAGLES.

From "The Building News."

The influence (all important and all pervading) which the persistent and unwearied attempts of twelfth century builders to erect over their buildings a substantial and permanent covering of stone, had on the architecture of subsequent times is now well known to all who have given any attention to the subject. It will probably be now admitted by every one that it was the working out of this problem which gave birth to almost all the distinctive characteristics of Gothic architecture, and the fanciful yet ingeniously supported theory that the "clustered and banded stalks of the lofty pillars, the curling leaves of the capitals and cornices, the interlacing arches of the fretted vaults" of the cathedrals of the Middle Ages, are attempts to reproduce in stone "the awful gloom of the deep forests of the North, the aspiring height of the slender pine, the spreading arms of the giant oak," must now be given up by all except the poetic "Quarterly Reviewer" who has the confidence to maintain that these glorious unities, these perfect wholes, were the result of a number of uneducated workmen each doing that which was right in his own eyes without consultation or superintendence. It was, I believe, Ware, in his "Tracts on Vaults" who first showed vaulting thus to be the final cause of Gothic architecture, but since his time the question has been more thoroughly worked out, notably by Viollet-le-Duc, who in his magnificent "Dictionnaire," in the article "Construction," says:—"The vault being from this time forward" (end of twelfth century) "the generator of all parts of a vaulted building, fixing the position, form, and arrangement of the supporting masses, is the first thing we ought scrupulously to study. By one who thoroughly understands the structure of the Gothic vault and knows the infinite resources its construction presents to view, all the other parts of the masonry can thence be naturally deduced." Dr. Whewell, too, the late Master of Trinity College, Cambridge, in his "Architectural Notes on German Churches," considers "that the adoption of the pointed arch in vaulted roofs arose from the requirements of vaulting, and from the necessity of having arches of equal heights with different widths," and further that "from its original situation in the vaulting, this form of arch was gradually diffused into other parts of the building." This view is indeed disputed by Professor Willis (whose admirable paper on the Vaults of the Middle Ages renders the volume of the Institute "Proceedings" in which it appears one of the most valuable of the entire series), for in the preface to his "Remarks on Architecture," he observes "There is a fascinating simplicity about that theory" (of the origin of the pointed arch) "which would derive it from the requirements of vaulting, that makes one wish to find it true; but I am sorry to say that notwithstanding the favorable prepossessions with which I set out, I have been compelled to dissent from this ingenious hypothesis. I have shown that so far from the pointed arch being necessary to enable a parallelogram to be vaulted, it appears that architecture was already in possession of several methods of performing this, which were not even superseded by the introduction of that form, but continued in use to the latest period of the Middle Ages." These methods are of course those which prevailed among the Romans, and which are now known as Roman vaulting, but the vaults constructed on these principles are kept up and maintained in equilibrium solely by the inert mass of the supporting piers, the area of which is very large; and which, thanks to the splendid quality of the mortar used, so good as to have become proverbial, are practically homogeneous throughout, the cohesion being perfect. This was indeed the principle of Roman buildings. The Romans secured stability by the sheer weight of the resisting portions of their buildings; if, for instance, they feared that an arch would rise at the haunches unless an enormous load was placed there, instead of seeking a more scientific form of arch they simply piled on the required load, and so for the rest. Now it was not only possible but easy for

* Royal Institute of British Architects' Prize Essay, 1874 Read before the Institute on Monday evening, June 1.

the Romans, a powerful people, possessed of abundant means and appliances, with armies of laborers, with any quantity of materials, and above all, with a great love of show and display, both of their wealth and power, to build in this manner. Economy to them was no object, but when we come to the twelfth century, to people just emerging from the barbarism and ignorance and consequent poverty of the centuries following the downfall of the Roman power, the case was altogether different. At first, indeed, they seem to have attempted to imitate the structures which the barbarian incursions had spared (for I should notice that it is to the Continent we must go for the earliest Mediæval examples), but they speedily found the impossibility of continuing this method. With them the most rigid economy had to be practised, the utmost possible effect had to be produced with the materials used; nothing could be laid to waste, and therefore instead of relying on mass and mere weight, the thinking faculty had to be exercised, and so attempts which were gradually, though doubtless only after repeated trials and occasional failures, crowned with success, were made to balance opposing forces, to diminish thrusts and pressures, and to make the direction of these as vertical as possible, thereby simultaneously enabling the area of the piers to be safely reduced. These circumstances, I think, acting on the ever-present desire in the twelfth century for stone vaults, led directly to the results produced, and furnish a reason why the previously existing Roman solution of the problem could not be accepted, and an answer to Professor Willis's objection to the theory in question. The question why stone vaults were so much sought after in spite of all the difficulties attending their construction, and why the builders of the day were not satisfied with wooden roofs, is a difficult one to answer. Probably the danger which there always was in these unsettled and turbulent times of the malicious or accidental destruction of any important building by fire, had something to do with the matter. Certain it is that such an event was by no means uncommon, and the use of the more durable and permanent material was thus perhaps in a manner forced upon the designers; for there can be no doubt whatever that a brick or stone shell over the building, whether the same be the actual roof or not, renders it to a very great extent fireproof. Even where (as is almost universally the case) the vault is only a sort of inside ceiling, and is protected from the weather by a timber framed roof above, a careless plumber can do very much less damage than where in place of the vault there is only a wooden or plaster ceiling, for by cutting off air from below, the fire is checked and more easily mastered, as was strikingly exemplified at Canterbury at the time of the fire there in November, 1872, for though nearly two hours elapsed between the breaking out of the fire and any water being brought to bear on it, still it was confined to the eastern limb of the cathedral (where it commenced), and since the burnt and charred timbers fell in on the upper surface of the vault, and so were prevented from dropping into the choir below, scarcely any damage was done to the interior of the building. It is not too much to say, then, that the existence to-day of this precious national monument is mainly due to its "stone ceiling," a very good reason for recommending similar construction where a durable building is required. On the other hand, York Minster, which is covered with a wooden ceiling of sham groining has twice within the present century suffered most severely from the ravages of fire. In 1829, the roof, the whole of the richly carved tabernacle work of the stalls, and, in fact, all the woodwork of the choir, were utterly destroyed, and it would be easy to multiply instances. Every one knows, however, that in England it was by no means the universal custom to ceil a building with stone; but if we compare the circumstances of our own country and those of our Continental neighbors, I think we may find reason for the greater prevalence of vaults there than at home, and which is of course another cause why the difficulties of vault construction were so steadily struggled against, and the system so pertinaciously adhered to. Our noble open-timbered roofs are legacies of which we may well be proud, which have no rivals abroad, and which we owe in no small degree to the magnificent forest of oak trees for which England was formerly famous. The Romans seem to have drawn heavily on the forests of Gaul after those of Italy were exhausted, for timber for their immense naval and engineering works, and hence even as early as the middle of the twelfth century the provinces where the first glimmerings of returning

civilization had appeared, and where consequently the architectural art was most advanced, appeared to have been almost entirely cleared, and as a natural consequence, wood became a comparatively scarce and proportionately valuable material. Whether this be the explanation or no, we have abundant evidence to show that vaulting had advanced a very considerable way towards perfection on the Continent at a time when it was very little if at all practised in England; that it was then imported as it were complete as it stood; and that it throve so well after being transplanted as soon to surpass its parent stock both in beauty of design and careful execution; no Continental examples, indeed, can compare with the richness and skill displayed in some of our late ones, though it may be doubted after all whether these last may not be adduced as instances of the "vaulting ambition which o'erleaps itself." I do not propose to enter into any discussion as to the antiquity or invention of the arch. Many of the so-called examples of its early use would be very much to the point if it were not for the unfortunate circumstance that they in no way exhibit its principle, but consist only of a series of corbelled out courses with horizontal beds—a method impossible of application to the covering in of extended areas. It is enough to go back to the days when Rome became a mighty nation and was enabled to indulge in those tastes to which I have already referred. The occasion of the rebuilding of the city after the burning by Nero seems to have been taken advantage of for covering in many buildings with vaults, which until then had only wooden roofs; and none of the great vaults with which we are acquainted seem to be of earlier date than this. * * * * *

There are one or two examples of Roman vaulting, consisting of a series of parallel transverse arches within a short distance of each other, on the backs of which thin slabs of stone are laid, connecting them together in pairs and completing the covering. This system obviously favored economy in the centreing required, as continuous planking might be dispensed with altogether; but it was quite exceptional, the transverse arches being generally hidden in the thickness of vault. There is obviously in many points a striking analogy between it and the rib and panel vaults of a subsequent period. The foregoing remarks refer strictly only to what is known as a continuous barrel vault. This is what the majority of Roman vaults were; semi-circular, of course, in section; in fact, in appearance exactly like the upper half of most of our railway tunnels. Interpenetrations seem to have been avoided, at all events until the later days of the Empire, and if, from the necessities of planning, an art in which the Romans seem to have been great adepts, a vault had to abut end on to the direction of another, they frequently got over the difficulty by making one (the smaller of the two) at a lower level than the other, so that the springing of the larger one would be above the crown of the other —the minor vault would finish as a semi-arch in the vertical abutment wall of the superior. We know, however, from existing remains, that the Romans did not entirely shirk interpenetrations of curved surfaces, and this really brings us to the difficulty of the subject—groined vaults. If we have to cover in an exact square, there is obviously no reason why we should choose one pair of sides for direction of axis of our barrel vault, rather than the other; at least, if we are not hampered by any considerations of convenience in securing the necessary abutment; in fact, we might suppose a complete barrel vault to be turned across in each direction, and supposing that the two could co exist, the space below would obviously have a double covering. Now if we imagine the part of each vault which is above the upper surface of the other cut away, we should have remaining a sort of square dome, which would form a single covering over the entire space; while if we cut away the part of each vault which is covered by any part of the other, *i. e.*, which is below its under surface, we should have a roof with salient edges or groin over the diagonals of the compartment, and which no longer abuts continuously along its sides, but the entire thrust of which is transferred to the four angles, and which might be carried on piers there placed. Both these methods were used. The first is known by French architects as a vault "en arc de cloitre," the second is the ordinary "groined Roman vault."

Thus far all is plain sailing; the compartment to be vaulted being square, the diameters of the arches on each pair of sides (the generators of the respective vaulting surfaces) are equal to each other; the crowns in the centre of the compartment and the groins are plain curves. Each being only an oblique section of a right circular cylinder, its outline would

be a semi-ellipse, and by constructing wooden centres to this outline, arches could be thrown across from angle to angle of the space to be vaulted, and the entire vault could be completed exactly as before described, the only requisite to be observed being that the centre should be so much larger than the actual finished groin as the breadth of the tiles used required, in order that their angles should not project beyond the finished vaulting surface. As soon, however, as we attempt to cover in a parallelogram with the groin vault difficulties beset us, which are the greater the more the parallelogram departs from a square. The sides being equal, if we use barrel vaults, semi-circular in section, for the generating surfaces of our groined roof, we cannot at the same time have the springing line and crown of the smaller level respectively with the springing line and crown of the larger; but if we make both spring at the same level, the crown of the one is below the crown of the other, while if we make their crowns level, the springing line of the smaller is more or less above that of the larger. In both of these cases the groins are no longer plane curves. Notwithstanding these difficulties, vaults were constructed with these groins of double curvature, notably over the great hall in the Baths of Diocletian, now the Church of Sta. Maria degli Angeli, but the compartments do not differ greatly from a square on plan, the sides being as 4 to 5, the span 67 feet; yet even here the effect of the twist in the groin is, by universal testimony, exceedingly disagreeable to the eye, and causes a painful sense of insecurity. In the great hall of the Baths of Caracalla, the mere springing of the vaults remains, yet there are clear indications of the twist; the proportions of the sides of the compartments here are as 9 to 11, or a trifle more nearly square than the preceding. In consequence of these difficulties and objections, Professor Willis, in his "Remarks on the Architecture of the Middle Ages," observes: "It is no wonder that a new expedient was soon found to supersede it" (the twisting groin) "which appears to be the domical or inclined form of the vaulting cells." (The vaulting surfaces filled in between the supporting arches, or a skeleton framework.) "The whole difficulty of vaulting a parallelogram with quadripartite vaulting resides in the assumed necessity of preserving the apex of the vaulting cells horizontal, and making their surfaces cylindrical throughout. If we free ourselves from these conditions, it is easy to show that we can not only vault any parallelogram or trapezium, but that we make both arches and groin of any figure we choose. * * The ridge line of each cell, which may be curved or straight, will of course be more or less inclined according as the apex of the lateral arches is more or less below or above the intersection of the groin-ribs. In fact, this reasoning is entirely independent of the form of the arches, and bound only with the one condition that the diagonal groins must intersect in some point, and therefore gives a complete solution of the problem with semicircular arches only. Pointed arches might naturally be used instead of semicircular ones, after their discovery or introduction, and their convenience and strength would occasion them rapidly to supersede the latter. But that there was no necessity for their employment is clear, because this expedient of forming domical cells was known to the Romanesque builders, and used by them at Spires and other examples of the same age, before the pointed arch made its appearance. Nay, I am by no means certain that it was not employed earlier, for I have already shown that domical cells are to be found at Baiæ, in the Temple of Venus, and elsewhere, although I am unable to cite an example of them in a genuine Roman cross-vault." The roof of the above-mentioned Temple of Venus, however, it should be noticed, is a genuine dome on a cylindrical supporting wall, and not a vault over a rectangle. Summed up in the above short description, we find noticed the introduction of a principle of the greatest, in fact of quite cardinal importance in the construction of vaults. It is the vital point of difference between Roman vaults and those of the Middle Ages; introduced by Romanesque architects in a tentative sort of way, it was developed by them to a considerable extent, but could not get full scope while restricted to the use of semi-circular arches, and, I believe, the pointed arch followed naturally from the attempts that were made for its perfect development. It will be noticed that in the genuine Roman vaults the vaulting surfaces are of the first consideration, and the groins are merely the result of simple interpenetration of two or more cylindrical surfaces; this followed

naturally from the minds of these architects being preocupied with the simplest possible form, the semi-cylindrical continuous barrel vault, and the changes to which Willis refers was certainly not so simple a one to make as he seems to imagine, and was never adopted by Roman as distinguished from Romanesque architects at all. Between the building of the baths of Diocletian and of the cathedral of Spires was an interval of nearly 700 years. The new principle introduced was of course that of making the groins regular curves, in no way dependent on the curve adopted for the vaulting surfaces over the sides of the compartment, and adapting the surfaces of the immediate vaulting cells to the outlines thus given to the "skeleton" framing of the vault. In the Roman method the vaulting surface was everything; it was made perfectly regular; the groins were subsidiary, and, as it were, an incident of the construction; in the new method the groins were of equal consideration with the bounding curves over the sides of the parallelogram, and the intermediate filling in became of but secondary importance. The true key to the solution of the problem of vaulting construction had now been found, a new path had been opened by travelling along which most of the difficulties which had beset previous efforts were avoided, and an impetus was given to the art which produced the happiest result. Working on this method, nothing, in the words of one of our greatest living architects, "is simpler than a good vault. The best rule for it is to make a good diagonal arch and a good transverse arch, and the filling in of the cells is pretty sure to take care of itself." The pointed arch was still, as I have said, necessary for the perfection of the new method, and for this reason: In a rectangle, the sides of which are, say as 2 to 1, the semi-circular arch on the diagonal (*i.e.*, the groin arch) will be more than twice the span of the semi-circular arch on the short side (the wall arch), and hence if we make these arches spring at the same level we must have a piece of dead wall (in height more than half-span of side arch) in order to raise the side walls of our compartment to the level of crown of diagonal arch. In order to allow the tie-beams of the sheltering roof to clear the vaulting, the side walls obviously had to be raised to this level, and hence the adoption of this method required an expenditure of labor and materials producing no adequate effect, which could not but be distasteful to builders possessing only such limited resources as did the early Romanesque builders of France and Germany. If, on the other hand, the crowns of the side arches were raised to the level of those of diagonal ones (*i.e.*, if the side arches were stilted more than half their span) it would follow that a horizontal plane through springings of side arches would cut the diagonal arches, and the vaulting surfaces would have to be skewed and twisted in a very peculiar manner.* The same objection would apply if we made the diagonal rib segmental, *i.e.*, if we made its rise equal to half-span of side arch, and in addition there would arise an awkwardness and unsatisfactory effect of the arch starting out of its pier at a decided angle, instead of growing gradually out of it in the manner so distinctive of perfect Gothic. All these methods and combinations of them were, however, adopted in the earlier days of the Romanesque period, the latter half of the eleventh, and the whole of the twelfth century; but an expedient which perhaps obtained more favor than any other was the following: The difference in the rise of the diagonal and side arches is less when the compartment is square on plan than when it is any other rectangle; the naves of early Christian churches were generally made almost exactly twice the width of the side aisles, and the span of the arches of the nave arcades was equal to width of aisles, hence the aisles were made up of series of squares on plan, and the vaulting there was comparatively simple; then, in order to get square vaulting bays in the nave, two compartments of the nave arcade were taken in to form each bay, and the diagonal arches were consequently supported by alternate piers, the distinction between those which carry both nave and arcade and superior vaulting, and the intermediate ones carrying arcade only, being variously marked. "This mode of vaulting with semi-circular arches both ways and with no diagonal ribs, is still found in several ancient churches, though it has often been replaced by more modern vaults. It is found with considerable dimensions in the churches of S. Maurice

* In vaulting of all periods we frequently, indeed generally, find the wall rib stilted, and the consequent twisting of the vaulting surface, but the height of the stilt is much lessened by the use of pointed arches; by its use excessively acute arches are avoided.

and S. George, at Cologne; the ancient monastery churches of Laach, near Andernach, and Eberbach, near Elfield; and on still a grander scale in the gigantic cathedral of Spires, where the span of the vault is about 45 feet; and though the storms of war have so often and so fiercely burst upon this city, it is confidently asserted by the most learned antiquaries that part of the vaulting is of its original form. In most of these instances, and especially at Spires, the compartments are considerably domical, the intersection of the diagonals being higher than the summits of the bounding arches."* The method, however, can only be deemed an expedient, and an evasion, not a solution, of the problem of how to vault over a parallelogram. The pointed arch alone enables this to be completely and satisfactorily accomplished, as with it we can make an arch of any span and any height. Suppose we have to construct a groined vault over a rectangle 40 feet by 20 feet, the length of the diagonal will be 44 feet 8 inches nearly, and a semi-arch described on it will rise about 22 feet 4 inches. If we decide to make our ridges level, the arches over the sides may be made of the following forms: The transverse arch may be struck with the same radius as the diagonal, and the radius of the wall arch (over the short side of the rectangle) will be 30 feet. There is here no waste of space, the filling in of the spandrels is simplified, and the construction is comparatively easy. We have now reached a stage when a fresh feature is introduced. In genuine Roman vaulting the ribs were almost, without exception, hidden in the thickness of the vault; the filling in was packed in between them, and the intrados, or under surface, was flush from one end of the building to the other; it became a homogeneous crust without elasticity, and which ruptured if by chance there was any settlement of the walls; but the very earliest Romanesque builders seemed to have aimed at securing a certain amount of elasticity in their structures (which indeed economy imperatively demanded), and their vaults were formed of shallow courses of unhewn stone, bedded in mortar, but arranged as quasi voussoirs. To stiffen these shells, transverse arches were turned across from pier to pier; but instead of being hidden in the thickness of the vault, they were built underneath it, appearing as projections from the general surface, and forming a permanent centreing. These are referred to by Whewell in the quotation just given, and on reference it will be seen that he also points out that similar arches run from pier to pier along the clerestory wall. This was a further carrying out of the elastic principle: obviously by it the whole weight of the vault was carried directly by the piers, the clerestory walls being relieved of all pressure from it, and these arches could follow any small motion of the piers, accommodate themselves to their settlement or spreading, and still the concavity of the masonry shell above them be secure. To carry the principle to perfection, the groin or diagonal arch obviously required to be made to project like the transverse and wall arches, and then we get the full complement of projecting ribs, and the great æsthetic principle of the constructional parts being made visible and prominent was fulfilled—we have now perfect *quadripartite* vaulting, so called because it will be seen there are four vaulting compartments or cells in each bay, the development of each of which is a sort of triangle. The introduction of visible ribs was the cause of a somewhat singular modification of the method already noticed, in which two bays of the nave arcade were taken to form each bay of the main vault. It was felt, I think, desirable to remove, if possible, the inequality which necessarily existed between the alternate piers of the nave arcade. To effect this, transverse ribs were thrown across between every pair, but the diagonal ribs were turned precisely as before, and each pair consequently not only intersected each other, but also the crown of the alternate transverse rib. This transverse rib could not be left a mere stone arch supporting nothing, and at first probably a vertical wall was built on it up to the crown of the vaulting cell, resting on the diagonal and wall ribs. An instance of this still exists in the Abbaye aux Dames at Caen; but a subsequent improvement was to make the wall ribs one instead of two bays of the nave arcade in span, thereby forming in each complete vaulting bay six compartments or cells, the ridges of which would radiate from the centre of the bay to the crowns of the four wall and two main transverse ribs respectively; the four cells abutting on the clerestory walls being, of course, unsymmetrical about the ver-

* Whewell's "Notes on German Churches."

tical planes containing their ridges. There are numerous examples of this method—notably the Abbaye aux Hommes at Caen, contemporary with the Abbaye aux Dames; and in our own country the Choir of Canterbury. It may not be without interest to notice that in Sir G. G. Scott's competition drawings for Edinburgh Cathedral the choir is shown vaulted in this manner, which, from the number of cells in each bay, is known as *sexpartite*. With the introduction of the pointed arch and the thorough admission of the principle above mentioned, the making the ribs a sort of permanent centreing on which the filling-in could be laid, the principal difficulties of vault-construction may be said to disappear. Much, of course, remained to be done, but chiefly only affecting matters of detail, which the practical experience gained by every building raised tended largely to explain and show how improvement might be made. Such a point was the starting the ribs from the supporting pier. At first a single vaulting-shaft ran up the face of the clerestory wall—generally from the nave floor level, being attached to the nave pier, though sometimes starting from its capital or from a corbel in the spandrel between the nave arches, and on the abacus of this single shaft had to be found room for the springing of the transverse ribs, the two diagonal ribs, and the two wall ribs, though these last would appear to have been frequently omitted. At first no attempt was made to make the various ribs mitre or penetrate into each other, but each started independently from the supporting abacus.

* * * The necessity for providing a large area for the sitting of the springers of the various ribs frequently led to separate shafts being provided for the support of each rib, which thus each had a separate capital from which to spring. We have here obviously the first germ of the clustered six. A very early example is given us in the nave aisles of Peterborough Cathedral. The nave is covered with a wooden roof, and was probably never intended to be vaulted, since shafts for the diagonal ribs are only provided next the aisle, while the half-shaft towards the nave, instead of stopping at the string under clerestory windows, which would be the springing line of the vault, is continued right up to the string over the clerestory window arches, and there finished abruptly. The tie-beams of the original roof probably rested on them, though these have, of course, disappeared. I was unable to get the exact curvature of the ribs of these aisle-vaults. the transverse ribs are semi-circular and considerably stilted, while the diagonal ribs are segmental, with their centres some distance below the springing line. The effect of this is to throw the diagonal ribs forward; so that looking down the aisle, part of each transverse arch is cut off, as it were, by the diagonal rib in front of it; and in order to avoid excessive twisting of the vaulting surface, each diagonal rib has to have a backing piled on its extrados, upon which, as on a centre, the actual filling in is laid, exactly as noticed by Professor Willis in the castle at Newcastle-upon-Tyne, and in the ruins of Finchall Priory, Durham. The transverse rib consists of two rolls, with a V-shaped member between them, while the diagonal ribs are exactly like those of the preceding example. The next great improvement consisted in making the ribs run into or penetrate each other. This of course greatly reduced the area of the vaulting springer, and consequently also that of the supporting pier. As the principle, too, of Gothic vaulting was worked out, and the logical consequences of that principle freely and fearlessly followed and admitted, we find a change in the general outline of the ribs. Hitherto their breadth has been greater than their depth (the dimensions below the vaulting surface); but since the stability of the vault depended on these ribs, which were, in fact, a series of independent arches, a reversal of these proportions was the necessary and logical result of a due consideration of the property of the arch "that its stability increases with its depth." This, too, assisted in the concentration of the ribs, so to speak, on the supporting abacus. Careful management is required to make the various ribs mitre into each other properly. With ribs of various curvature, we are liable to find some particular one disengaging itself from the spandrel solid before its neighbors, which introduces a certain amount of awkwardness. This is noticeable in the vault over the chancel of S. Mary Minster, Thanet. It consists of four bays of quadripartite groining of varying widths, the first of which from the west is wider than the others. The transverse ribs are very obtusely pointed, almost semi-circular; the ridge from east to west is level. Their outline is segmental, not pointed, and consequently the

centre from which each is struck is at a greater or less distance below the springing line according to the greater or less width of the various bays. The various ribs in the spandrel solids all mitre very fairly; but owing to the greater span of the ribs, and their consequent greater obliquity to the vertical at their springing, they are thrown forward, and become detached from the rest before these last are completely developed, and the awkwardness spoken of ensues. The principle of making the ribs interpenetrate introduced a very important detail of construction. This consisted in forming the blocks of masonry at the springing (to a height such that the ribs by their spreading had completely disentangled from each other themselves, and could each be continued as a separate arch formed of independent voussoirs), with horizontal courses. This block is known by its French name of the *tas de charge*, there being, I believe, no equivalent term in the vernacular. The first two or three courses of the spandrel solid would each be worked out of a single stone only, and the pressure exerted by the various ribs being thus brought together in a single mass of material of comparatively limited area, would necessarily combine and produce a single resultant, the action of which could be resisted by judicious buttressing. The genuine arch construction of each rib would therefore begin only when it became entirely disentangled, as it were, from the other ribs, up to such a point, the construction being in fact mere corbelling out. * * The irregular mitreing of the moulded ribs which was unavoidable when the various ribs were all of different curvatures, must, however, have been felt to be somewhat unsatisfactory and defective, and when vaults of great span and formed of wide bays were attempted, in which, for the additional security of the filling in intermediate ribs between the transverse and diagonal, and diagonal and wall ribs were introduced, matters became still more complicated. The solution of the difficulty was found in making each rib a compound instead of a simple curve. By this means each rib, no matter what its span, could be formed with its lower portion of any desired curvature, and thus the simultaneous development of adjacent sides of the various ribs from the spandrel solid could be ensured. * * In vaults where the ribs are numerous and all parts of the same curve (fan vaults), the spandrel solid becomes practically a solid of revolution generated by the motion of a simple or compound curve round a vertical axis. Our own country is their home par excellence; on the Continent architects scarcely went beyond the perfect quadripartite vault, and though our late and elaborate examples are triumphs of stone-cutting and technical skill, they exhibit scarcely any new principle, and with the perfecting of the earlier method the difficulties of vaulting may be said to have been overcome. Such vaults, indeed, as those of King's College Chapel, Cambridge, and Henry the Seventh's Chapel, Westminster, must be considered to some extent debased, and as exhibiting false construction, inasmuch as in them the ribs are not veritable independent arches forming a permanent centreing, on which a thin shell forming the filling-in is laid, but the vault is really of solid masonry, the apparent rib of panel work being mere ornamental sinkings in the solid stones of which it is composed. Gorgeous though they are, still I think they are really of minor importance, and the interest of the subject is to my mind to a great extent exhausted when the problem which the early Romanesque builders set themselves to work out was once fairly and fully solved. I will conclude these hasty notes with the following passage from Street's charming book, "Brick and Marble in the Middle Ages;" it is, I think, worthy to be constantly in the remembrance of every architect: "The real beauty of these interiors" (of the churches in Venice) "is owing, I believe, more to the noble simplicity and purity of the quadripartite groining which arches them in, and which, even where other features would seem to tell of debasement and absence of feeling, invariably recalls us to a proper recollection of the infinite value of simplicity in this important feature. * * * It is not difficult to prove that this must be the case, for I take it for granted that we all feel that ornament for its own sake is valueless, and equally that doing in a troublesome and therefore costly way that which may as well be done in a simpler manner, is unpleasant and distasteful as an exhibition of the wasteful expenditure of human skill and energy; and therefore, as simple quadripartite groining with diagonal and transverse ribs, and none intermediate, is quite sufficient for construction, and is in no degree whatever strengthened by the multiplication and ramification

of ribs, common even in our early work, and in later days sinking into the effete and senseless luxury of fan tracery and its contemporary modes of vaulting—that, therefore, the simplest is the only true and thoroughly defensible system of roofing in stone.

NEW AND ECONOMIC PUMPS.

From the "Mining Journal."

The extreme simplicity and great water-raising capacity of the very primitive form of pump met with in some of the old Spanish mines, and consisting merely of a wooden tube, of length corresponding to the depth of the shaft, with an endless rope carrying at intervals a bunch of sheepskin, has been admired and favorably reported upon, so far as the principle is concerned, by some of the most competent engineers who have been intrusted with the management of mines in modern times, but all have concurred that obvious want of durability and general roughness of the contrivance rendered the introduction of various improvements absolutely necessary to enable a pump upon this principle successfully to compete with the other forms of pump at present in use. It was seen at once, for example, that the square wooden box through which the water was raised would have to be replaced by a metallic tube, and that even in the improved kind of cylinder thus suggested the bunch of sheepskin was certainly not the most economic form of piston that could be adopted. The question then which presented itself for the solution of inventors was how to utilize this principle of lifting the water only without any dead weight (for it was admitted that in a properly-constructed pump of this class the descending pistons might be made exactly to counterbalance those ascending through the tube), and at the same time reduce to the minimum the friction between the tube and pistons, as well as that about the wheel by which the pistons were put in motion.

To the solution of this question inventors have energetically applied themselves during the past century, the first real progress being that made in the chain-pump, invented in 1790, by Mr. Deprony, who used an iron tube with a chain running through it, affixing upon this chain at short intervals from each other a series of discs, to which leather washers were somewhat roughly fastened to serve the purpose of packing. The hardening of leather after being in the water, and the impossibility at the date of the invention of obtaining a tube with anything like a smooth interior surface, gave rise to several annoying difficulties in the practical working of the pump—that of steering between too much friction on the one hand, and sufficiently tight packing to prevent the descent of the water when the pump was stopped, being the principle—led to the abandonment of the invention; but not before Deprony had done enough to prove that it was in mechanical details only that the chain-pump was defective. In the ordinary working of the pump a large quantity of water was raised with comparatively little power, but the misfortune was that perhaps at the most inconvenient moment the chain would break, and the whole series of discs would fall to the bottom of the pit, necessitating considerable delay in getting the pump at work again. This, coupled with the annoyance of the pump being temporarily unserviceable if it was left idle for a time, created a prejudice against the system which subsequent inventors have found it difficult to remove.

Notwithstanding this, various efforts have been made to perfect the pump, and it must be admitted that many inventors have made very important corrections of the mechanical defects, not the least of these being those embodied in the invention of Mr. Jules Bastier, which in the hands of an energetic Englishman or American would, no doubt, have realized a fortune, for although the difficulty of the breakage of the chain remained unsurmounted, and the discs were capable of further improvement, there was no question that Bastier had the germ of a good invention, which only required careful development. He recognized the fact that England and America were the most fertile fields for introducing an invention for the more economic raising of water, but with the most contracted notions of a Frenchman, and with such inability to learn our language that after ten years' residence in

England, he could not carry on an ordinary conversation, he sought to develop the invention single-handed, to superintend the manufacture himself, and demanded heavy royalties for the use of the invention; his constant challenge being, until he had reduced himself from affluence to poverty, that he would put down a pump at his own expense, but that if it worked as he promised, he would have his own price for it. From manufacturers who would have undertaken the working of the patents, and had influence to promote the adoption of the pump, he demanded 25 per cent. upon the selling price; the natural consequence being that the invention was neglected until the patents had expired, and the trifling modifications necessary to make the pump a practical success were never brought forward.

But the unsuccessful efforts of Deprony and Bastier have not failed to produce good fruits, and it is now confidently believed that the last of the mechanical defects which have hitherto prevented the general adoption of this principle of pumping have been removed. Mr. Francois Martin, of Rue Laugier aux Ternes, Paris, an ingenious mechanician, who has had considerable experience in the actual manufacture of pumps of this class, and has, therefore, had the best possible opportunities of observing the defects, and judging of the readiest means of removing them, has constructed working models of pumps upon the principle of the chain-pump, but in which the inconveniences referred to—the breakage of chain and defects of the pistons—are entirely overcome, and he is now seeking the assistance of an English or American capitalist to join him in securing the necessary patents. The action of the model is as near as may be perfect. The system which he uses for the packing of the pistons is admirable, since there is scarcely more friction than in the best form of steam-engine cylinder, although they are sufficiently tight to hold up the column of water for many hours. With material of ordinary quality it is most unlikely that any breakage would occur between the pistons more frequently than the breaking of the piston-rod of a steam-engine, while in the possible contingency of such a breakage the pistons would not, as in the chain-pump, fall to the bottom of the pit, but the evil could be remedied in five minutes. These facts, coupled with the circumstance that the pump can be cheaply constructed, should suffice to ensure its general introduction.

THE VALUE OF SUPER-HEATED BLAST IN THE WORKING OF BLAST FURNACES.

Translated from the German of Prof. Tunner by Mr. H. Rocholl.

"Journal of the Iron and Steel Institute."

Most metallurgists remember that on the first introduction of hotblast in the working of blast furnaces, the temperature of the same, taken at the tuyeres, amounted from only 150 degs. to 300 degs. C. (302 degs. to 572 degs. F.) Nevertheless, a saving of 15 to 30 per cent. and more of fuel was everywhere experienced, and the only objection against the use of heated blast was the circumstance that, in some instances, the saving of fuel was accompanied by a deterioration of the quality of the pig iron. Chemical analysis has proved a larger amount of silicon to be the cause of this pig iron being objected to. In all probability, this higher percentage of silicon results from the circumstance that heated blast produces a higher temperature, particularly of the lower part of the furnace, where the reduction of silicon takes place. The first and most natural means to diminish the temperature of the lower parts of the furnace, and to obtain conditions similar to those when using cold blast, was found in the increase of burden; but it appeared that this did not effect in all cases what was desired; in several instances a perfect reduction and the desired degree of carburization were not obtained. The limits of those conditions under which the pig iron is grey or white seem to approach each other so closely that, for a long time, particularly in Inner-Austria, metallurgists doubted whether heated blast could be advantageously used for a regular production of white iron. After a closer study

of the blast furnace process, however, another remedy against an excessive formation of silicon was found, which did not impair the reduction and carburization of the metal; a more basic slag, obtained by an additional quantity of limestone, appeared to have a firmer hold of the silicon, and to prevent its entering largely into the pig iron. This expedient is employed successfully in all those cases in which the ore does not already contain an excess of lime, for, by the presence of a large excess of lime, sulphur enters into combination with this earthy base. In some few cases, a widening of the crucible, or lowering of the pressure of the blast, is found useful; these expedients, however, are applicable only within narrow limits prescribed by other conditions. In all those cases where an increased proportion of silicon is not objectionable, but rather desired, the above-named means of reducing its amount are of course not used, and the introduction of heated blast under such conditions was, from the beginning, followed by the greatest success.

At the present time, hot blast, in consequence of the saving of fuel it effects, is of so universal application, that only exceptionally a blast furnace worked with cold blast is met with; but another question recently has arisen and is discussed eagerly among scientific and practical metallurgists, viz., the highest temperature at which an increased heating of the blast would be accompanied by increased economy. In England, ever since Neilson in 1827 introduced hot blast, a higher temperature has been worked with than in any other country. From England, particularly from the Cleveland district, recently has originated a considerable enlargement in cast iron hot blast stoves, as well as the introduction of Cowper's and Whitwell's stoves, by means of which iron smelters have been enabled to convey a blast of 500 degs. to 800 degs. C. (932 degs. to 1,472 degs. F.) into the furnace. In the same district particular attention has been paid to a scientific investigation of the blast furnace process, most prominently by Mr. I. Lowthian Bell. In England consequently, this question has originated, and there, most probably, will it first be decisively solved. This circumstance, however, does not exclude this matter from being again discussed in this place.

The majority of English metallurgists and iron smelters, according to the papers and discussions reported in the *Journal* of the Institution of Civil Engineers, pronounce the highest possible temperature of blast to be most economical, or at least they are of opinion that the limit beyond which increase of temperature does not increase economy has not yet been reached, still less exceeded. The other party, which believes that this limit has already been passed, at least in the Cleveland district, is headed by Mr. I. L. Bell, and for this reason their views call for closer criticism, as Mr. Bell recently has directed more attention and labor on the study of the blast furnace process than any other metallurgist.

A final settlement of this question is made more difficult by the circumstance that the consumption of fuel is influenced not only by the temperature to which the blast has been heated, *i. e.*, by the quantity of heat which it conveys into the furnace, but also by the dimensions of the furnace, which determine the degree to which the heat, conveyed into and generated in the furnace, is utilized. Not only the temperature of the blast, but, at the same time, the capacity of the furnaces has, of late years, been largely increased; consequently, it is difficult to make out for certain how much of the saving in fuel is due to the higher temperature of the air, and how much to the increased capacity of the furnace. If, besides, the material (ore and fuel) operated upon, or the quality of the pig iron, has changed, it will be still more difficult to assign to the increased temperature of blast its due share of the saving of fuel.

I shall begin by giving a short account of the opinions, investigations, and experiences, the publication of which has caused Mr. I. L. Bell to be acknowledged as one of the leading metallurgists of the present day.

Mr. Bell, in order to make out his case, assumes a blast furnace so large that the charge on going down may absorb the sensible heat of the gases, as well as saturate them with oxygen from the ore, as completely as is compatible with the nature of the blast furnace process. When in such a furnace the cold blast is changed for hot, say 485 degs. C. (905 degs. F.), it seems clear that, as far as intensity is concerned, the same should take place in a larger as in a smaller furnace, and the same extraordinary consequences should be

looked for, if really they were depending on the increased intensity. This, however, is not the case, for if the furnace is so large that it affords the time required for finishing in proper time the two processes of reduction and smelting, a unit of heat, entering it by way of the blast, cannot be more effective than a unit generated in the furnace itself by combustion of fuel.* According to Mr. Bell's view, it is therefore much simpler, and consequently more economical, to burn the whole of the fuel in the furnace itself with cold blast, instead of burning part of it in a stove, and heat the blast. In that case only, according to this theory, an advantage is to be gained by heating the blast, if it is done by a less valuable fuel which cannot be utilized in the furnace itself, *e. g.*, the furnace gases, or by impure and less expensive small coal, etc.†

This practically is the case, particularly as the furnace gases are universally used for the purpose; the question remains to be answered up to what extent the combustion of the expensive furnace fuel may economically be replaced by the heat of the blast.

The chemical laws according to which the power of CO of reducing oxides of iron diminishes in presence of CO_2, which acts as an oxidizing agent, establish a limit beyond which an increased temperature of blast is useless; with the increase of heat necessarily the proportion of CO increases, which is supplied by the combustion of fuel. Mr. Bell has shown by experiments that at 300 degs. C (572 degs. F.) a mixture of 100 vol. CO and 50 vol. CO_2 is indifferent to oxide of iron, as it occurs in calcined Cleveland ore, while the same quantity of CO mixed with 45 vol. CO_2 effects a partial reduction of the oxide of iron. This latter mixture, however, at 600 degs. C (1,112 degs. F.), has no longer reducing but oxidizing properties.

Mr. Bell, in consideration that the chemical action of this mixture is only slow, and the temperature increases downwards, assumes that a saturation of the gases with oxygen, to a degree corresponding to a mixture of 45 vol. CO_2 and 100 CO, does practically not take place, and he fixes for calcined Cleveland ore a proportion of 40 vol. CO_2 to 100 vol. CO as that at which no more oxygen is taken up. Mr. Bell calculates that for an ore which yields 40 per cent. and requires 15 cwt. of limestone per ton of pig iron, 93,000 calories are required per ton of pig iron.*

* No. 1.—In the zone of fusion :—		
Fusion of pig iron	6,600	
Do. of slag	17,000	
Decomposition of H_2O in blast	2,800	
Reduction of P_2O_5, SiO_2 and SO_3	4 000	
Expansion of blast	4,050	
Radiation from walls	450	
		34,900
No. 2.—In the zones of heated absorption, transmitted ... through the walls of the furnace.....	2,500	
No. 3.—In the zone of the decomposition of limestone :—		
Expulsion of CO_2.....	5,550	
Decomposition of do.....	5,760	
		11,310
No. 4.—In the zone of reduction :—		
Reduction of Fe_2O_3	33,100	
Carbon impregnation.....	1,440	
Evaporation of water in coke.	300	
Radiation from walls.....	650	
		35,490
No. 5.—Carried off in gases....		8,800
		93,000

To generate these 93,000 calories by cold blast at a proportion of 40 vols. CO_2 to 100 CO in the escaping gases, 25½ cwt. of good Durham coke are required. Now, as this proportion of CO and CO_2, calculated from the amount of oxygen to be removed from the ore, requires only so much carbon as is contained in 21 to 21½ cwts. of coke, it follows that 4 out of these 25½ cwts. may be saved if the heat (represented by those 4 cwts. of coke) is conveyed into the furnace by way of the blast. This is accomplished by heating the latter to about 485 degs. C. (905 degs. F.) What, however, will be the result when the blast is introduced into the furnace at about 800 degs. C. (1,472 degs. F.)? Evidently this additional heat will increase the temperature of the whole contents of the furnace, and on reaching the zone of reduction, will enable the CO_2,

* Nothing can be said against this; on the contrary, the general abandoning of Cabriol's hot blast stove confirms this view. Quite different, however, are the conditions when the blast introduces only the heat, not the products of combustion, from the stove into the furnace.

† The advantage to be gained by the more perfect combustion obtainable in stoves compared with the combustion in the blast furnace (which yields more CO_2) cannot be of much consequence, it being counterbalanced by the considerable amount of heat escaping in the waste gases of the stoves and lost by radiation between the stove and the tuyeres. More important is the convenience which changing the temperature of the blast affords for quickly regulating the working of the furnace.

which was inert at the lower temperature, to take up carbon in the now increased temperature.

This gasification of carbon in the zone of reduction, and consequent diminution of the quantity arriving in the zone of combustion, will again lower the temperature of these two zones, and, finally, as the excess of heat conveyed into the furnace increases, the proportion of CO_2 in the furnace gases will decrease. Mr. Bell always has found proof of these reactions in his investigations on the subject, and he shows, from the results of a furnace at the Barrow Iron Works, and some furnaces of the Middlesbrough district, that the highly-heated blast from Whitwell stoves, compared with blast heated to only 450 degs. or 500 degs. C. (842 degs. to 932 degs. F.), did not effect any further economy of fuel.

Mr. Bell admits brick (Whitwell) stoves to possess considerable advantages over cast iron ones, but for sufficiently large furnaces he does not put any value on their power of giving constantly a temperature of 500 degs. C. (932 degs. F.), simply because such a high temperature is useless. If, however, the particular nature of certain ores or fuel necessitates the use of small furnaces, the more highly-heated blast proves a valuable help. The power of the blast furnace gases of taking up oxygen reaches, according to Mr. Bell, its limit when 30 per cent. of the CO are transformed into CO_2. Consequently, when this proportion is reached, further economy ceases, as they have no further reducing power.

From Mr. Bell's lengthened experience, it appears that a furnace 80 feet high, and of a capacity of 12,000 to 16,000 cubic feet, has all the advantages which can be gained by increasing its size; furnaces of a capacity up to 41,000 cubic feet, which lately have been erected in the North of England, have not realized corresponding advantages. According to Mr. Bell, in a furnace of 16,000 cubic feet, the limit is reached to which the waste gases may be cooled and saturated with oxygen; nor does the production of pig iron keep pace with the increasing size of the furnaces, as is evident from the following data:—

Cubic capacity of furnace, in cubic feet ...	6,000	12,000	16,000	26,000	41,000
Weekly production, in tons	220	260	350	400	550
Weekly production per 1,000 cubic feet, in tons	37	23	22	16	13

I mention one more statement which Mr. Bell has experimentally proved. As the quantity of heat carried away by the waste gases is represented, even with the largest furnaces, by 2 to 3 cwts. of coke per ton of pig iron, Mr. Bell, in order to gain a better insight into the circumstances affecting the temperature of the upper part of the furnace—termed by him the zone of reduction—has made the following experiment: He replaced in a regularly working furnace the burden of calcined ironstone by an equal weight of slag and flints, a mixture perfectly neutral to CO, and continued this mode of charging for many hours. The result was an immediate fall in the temperature of the gases, and subsequent rise as soon as calcined ironstone was again charged. This experiment seems to prove that, in contradiction to the usually adopted assumption, a development of heat takes place in the reduction of oxide of iron.

As the work of the blast furnace consists not only in the smelting of the charge, but, at the same time, or rather previously, in the reduction of the oxide of iron and immediate carburization of the iron produced, it is clear that for the performance of these processes a certain weight of fuel is necessary. Now, if it be universally correct that the power of the blast furnace gases of taking up oxygen, without simultaneously re-oxidizing reduced iron, ceased as soon as they contained 40 vol. of CO_2 on 100 of CO; furthermore, if in the large furnace the reduction of the ore really be completed at a temperature of 400 degs. to 500 degs. C. (752 degs. to 932 degs. F.), nothing could be said, in my opinion, against Mr. I. L. Bell's theory and calculations, at least as far as it concerns the production of white iron. But a much larger proportion of CO_2 exists in the gases from our furnaces which smelt easily reducible ores by means of charcoal, as is shown in Messrs. R. Richter and R. Shœffell's analyses published in this journal (Berg-und Huettenmaennisches Jahrbuch), and the reduction is completed at a much higher temperature, below the boshes, as well as in our furnaces, according to Prof. Kupelwieser and Schœffell's and my own observations, as in the Swedish charcoal furnaces, as shown by M. Rinman. This latter statement that the reduction is completed at a higher

temperature of 800 degs. to 1,000 degs. C. (1,472 degs. to 1,832 degs. F.) is corroborated by Dr. C. W. Siemens, at least for the denser kinds of iron ore, *e.g.*, magnetic ore. Mr. Bell himself, in his several publications on this subject, has repeatedly stated that his calculations in the first instance refer only to Cleveland iron ore. Under these circumstances the discussion of the economical value of super-heated blast does not seem a superfluous one, notwithstanding Mr. Bell's most valuable work on the subject.

I first will try to show by calculation that the proportion of Co_2 to CO in the waste gases of our furnaces must be considerably higher than 40 vol. of the former to 100 of the latter, corroborating Messrs. Richter and Schœffell's analyses, the correctness of which from some sides has been doubted.

Adopting Mr. Bell's mode of computation, calculate the quantity of heat absolutely necessary for the production of 1 ton of white pig iron in the Inner-Austrian charcoal furnaces as follows:—

	Units.
1. Evaporation of water in charcoal.....	400
2. Reduction of ore and carbon impregnation.....	32,400
3. Decomposition of moisture in blast.....	1,600
4. Heating and fusion of pig iron (Rinman).....	6,800
5. Do. of 14 cwts. of slag (Rinman).....	6,160
6. Reduction of silicon and other impurities.....	1,000
7. Transmission of heat through walls of furnace and heating of tuyere water (Bell).....	3,840
8. Heat in waste gases, escaping at a temperature of 300 degs. C. (572 degs. F.	6,600
	58,800*

This quantity of heat is generated, the furnace working regularly and with a blast of 300 degs. C. (572 degs. F.), by a charge of 14 cwts. of charcoal, containing about 12·6 cwts. of pure carbon. After deducting ·9 cwts., as the quantity taken up per ton of pig iron, there remains available for combustion 11·7 cwts. of carbon.

	Units.
This quantity on burning to CO yields 11·7 248 =	29,016
60 cwts. of blast of 300 degs. C. yields ·237 × 60 + 300 = ...	4,266
Total	33,282
The required quantity was	58,800
Leaving to be supplied by combustion of CO to CO_2	25,518

In order to generate this heat $\frac{25518}{2400}$ = 10·64 cwts. of CO have to be burnt to CO_2. Now the above 11·7 cwts. produce 27·30 CO, so that after deducting 10-64 there remain unchanged 16·66 cwts. CO. Consequently, in order to generate 58,800 units, 16·66 CO and 10·64 $\times \frac{22}{14}$ = 16·72 CO_2 or by volume 64 CO on 100 CO) have to be formed. Herr Schoffel found, in 1871, * 58·3 CO_2 on 100 CO; Herr Richter's analysis of 1859 shows even more CO than CO. We certainly may conclude that the proportion of 40 CO_2 to 100 CO, on which Mr. Bell's calculations are based, cannot be universally accepted as true.

If, as Mr. Bell assumes, the reduction of oxide of iron be effected only by CO, and the whole of the iron brought into the furnace in the state of $Fe_2 O_3$, the redution of 19 cwts. of iron would require 14·2 cwts. of CO and produce 22·2 CO_2, while, according to the above calculation, the generation of the necessary heat requires only the formation of 16·72 CO_2. If, in the process of reduction, 22·2 cwts. of CO_2 were formed, the weight of CO remaining, at a consumption of 14 cwts. of charcoal, would be only 13·1 cwts., consequently 108 vols. CO_2 on 100 CO would result, a proportion which, by the late Prof. Richter, has actually been shown to exist in the gases from the Wabna furnace at Eisenerz.

However doubtful it may seem, after more recent investigations, whether such a large proportion of CO ever does occur in furnace gases, certainly there can be no doubt that in the working of our blast furnaces for white iron, under the conditions on which the above calculations are based, the reduction of the ore demands the formation of a larger quantity of CO_2 than the generation of the heat required for the smelting necessitates, and consequently that, in accordance with Mr. Bell's theory, a higher temperature of the blast cannot be accompanied by a greater saving of fuel. It seems a vain endeavor exactly to fix the highest temperature at which, in our production of white iron, the heating of the blast is accompanied by a corresponding saving of fuel; the doubt which still exists about the conditions under which the re-

* This figure is more likely too low than too high, the absorption of heat by expansion of the blast not being taken into account. The quantity of this certainly amounts to more than the heat, which, as Mr. Bell has proved, is generated in the reduction of the ore, and which has been neglected in this calculation.

* Berg und Huettenmaennisches Jahrbuch of 1873, p. 188.

duction of the oxides of iron takes place, does not allow the assumption of incontestible bases for calculation; however, so much seems almost certain, that at a temperature of 300 deg. C. (572 deg. F.), the limit is not only reached, but most probably passed. Thus the erection of the more expensive hot blast stoves (large cast iron ones, or Whitwell's), for our blast furnaces in the production of white iron is only so far of advantage as the temperature of the blast, which can be regulated at will, and raised very high, affords a convenient means of regulating the work of the furnace.* Very different, however, are the conditions under which grey iron is produced in Inner-Austrian blast furnaces, respecting which, since the introduction of the manufacture of the deep grey Bessemer iron, several valuable observations have been made.

In Neuberg formerly, at a temperature of blast of 200 degs. C. (392 degs. F.) and a yield of 44 to 45 per cent. of pig iron, 15·4 to 15·6 cwts. of charcoal were used per ton of white iron, and 23 to 24 cwts. per ton of grey iron, *i. e.*, 50 per cent. more fuel was consumed for the production of grey Bessemer iron than was used for white. Lately, by heating the blast to about 500 degs. C. for the production of Bessemer iron, the consumption has been reduced to 19 to 20 cwts., a saving of more than 25 per cent. against the weight required at a lower temperature. In the Carinthian blast furnaces at Loelling, Treibach, and Heft, many years since, only 12·6 to 14 cwts. of charcoal were used per ton of white pig iron, at a temperature of blast of 160 degs. to 200 degs. C (320 degs. to 392 degs. F.) and a yield of 50 to 54 per cent. At Treibach, a further economy of fuel on using hotter blast has been asserted, but afterwards doubted; only so much is certain that the quality of the white iron produced at a temperature of blast of 500 degs. C. (932 degs. F.) has been by all consumers objected to, and its production has been accompanied by many irregularities. For the production of grey Bessemer iron of first-rate quality, however, at Heft, the consumption of charcoal has been reduced from 20 cwts. and more at 200 degs. C. (392 degs. F.) to 17 to 18 cwts. at 350 degs. to 400 degs. C. (662 degs. to 752 degs. F.)

It seems certain that at Triebach, when with the use of highly heated blast the burden was considerably augmented, in order to avoid the formation of grey iron, a perfect reduction did not take place, in consequence of which, what is called a boiling slag (Kochschlacke) formed in the crucible of the furnace. In consequence of the boiling the pig iron grew porous, intermixed with slag, though still of a greyish character, owing to the high temperature at the tuyeres. At Heft and Neuberg, however, in the production of grey iron with a consumption of 17 to 20 cwts. of charcoal, even at a high temperature of the blast, the quantity of CO required for complete reduction is present in sufficient quantity.*

This difference in the value of superheated blast for the production of white and grey iron, not at all entered into by Mr. Bell, is of particular importance for our easily fusible, mostly manganiferous ores; for in smelting these ores the difference in the consumption of fuel for the one or the other quality is considerable, and even in the most favorable case the quantity of charcoal required is so large that a deficiency of carbonic oxide is not to be feared.

I believe, in consideration of these facts concerning our charcoal furnaces, that in the smelting of easily reducible ores with charcoal the proportion of CO to CO_2 may reach 60 vols. CO_2 to 100 CO. If in the production of white iron at a temperature of blast of 200 degs. to 300 degs. C. (392 degs. to 572 degs. F.) the quantity of CO_2 in the waste gases does not come up to these proportions, then greater economy may be expected from a higher tempera-

*I must confess that formerly I have put too much trust in several communications which I received as to the saving of fuel, consequent on the use of highly heated blast in the production of white iron. The charge of charcoal being universally measured by volume, I have lately had made exact determinations of the weights of many charges by some of my younger fellow-workers, and so found inaccuracies in several of my former figures.

*I would not by any means dissuade smelters from constructing larger hot blast (cast iron or brick) stoves for our furnaces, which at present are worked for white iron. Such stoves, besides being periodically useful for regulating the working of the furnace, are certainly of greater durability; besides, the demand for Bessemer iron increases annually, and undoubtedly in a short time our iron ores, being so exceedingly poor in phosphorus, will be universally smelted for Bessemer iron, so that the production of white iron, now almost universally practised, will be the exception.

ture of blast, without impairing the quality of the pig iron. A deterioration of the same will in any case be owing rather to a cold working of the furnace than to an increased reduction of silicon, which latter is easily prevented by the means enumerated above.

The considerable advantage of highly heated blast for the production of Bessemer iron above referred to, and proved by the results obtained at Neuberg and Heft, is owing, I believe, not only to the higher consumption of carbon generating an excess of carbonic oxide, which is required for this quality of iron, but no less to the circumstance that in using highly heated blast, the temperature of the upper part of the furnace is relatively lower, and of the lower parts higher than is the case with cold or moderately heated blast. Though I must own that I have not succeeded in proving the increased intensity of highly heated blast in experiments which I performed in the laboratory of the Mining Academy at Leoben, with the assistance of Prof. Kupelwieser and Schœffell, so much, however, is certain, that on using heated blast (unmixed with the gases of combustion from the stove), a higher temperature must exist in the lower part of the furnace than with cold blast, because, in the first case, the same quantity of gas, and equally the temperature of the upper part of the furnace, must be lower, because, with the smaller quantity of gas and increased burden, the absorption of heat must be quicker and more complete. This is proved by the frequently observed fact that in using hot blast, the lower parts of the furnace are more rapidly eaten away than with cold blast. This distribution of the heat is a necessary condition for the production of grey iron, which, when cold blast is used, can only be gained by a greatly increased consumption of fuel.

LIGHTNING CONDUCTORS.

From "The Engineer."

Father Secchi, the well known astronomer and natural philosopher, has recently carried out some very interesting researches on the action of lightning conductors, which deserve some notice at our hands, and the particulars of these researches have been prepared by Mons. G. Duguet, and published by him in the "Bulletin" of the last number of the *Revue Universelle*. The circumstances we are about to relate took place some four years past at Alatri, where about the same length of time previously lightning conductors had been placed on the two highest points of the cathedral and Episcopal Palace, which crown what we may term the acropolis of the town. It would appear that there was some little difficulty in satisfactorily fixing the conductors, inasmuch as a short distance below the surface of the soil a compact calcareous rock was met with; however, they were eventually placed so that they had penetrated to a depth of four metres, and were furnished with barbed points, five centimetres wide, five millimetres thick, between which was twisted a strong copper wire, with the object of increasing the contact between the conductors and the charcoal in which they were immediately immersed. The inferior portion of the conductor, to the length of one metre above the surface of the earth, was of copper, at which distance it was united to the iron in a box placed in the lower part of the building; the gutter in which wires were laid was five metres long, with a section of sixty centimetres, and was carried as far as the roots of some neighboring trees, where it was anticipated the soil would always contain a certain amount of moisture; and the bottom of this gutter had a bed of pulverized charcoal twenty centimetres thick. It is to be understood that the separate conductors in the belfry and choir were connected by a bar of iron, with the object of giving, in case only one point was struck, the fluid the facility of two roads of escape.

The effect of these arrangements was so far satisfactory that, although the belfry was four times touched, no damage whatever ensued, until, on the night of the second of November, 1872, a terrific storm burst over the town, when the belfry was struck twice without any harm resulting, and again a third time with the effects we are about to relate, premising, however, that about four years previously cast iron

piping had been laid down for the water supply of the villages of Alatri and Ferentino, and the distributing apparatus for the same was placed in a building but a few yards distant from the belfry ; there was, however, no communication between the piping and the conductor.

We now come to the facts. At the third discharge on the night in question the electric fluid, starting from the lower end of the conductor, struck across towards the line of pipes leading to Alatri and Ferentino with the following effects :—(1) It ploughed out a trench, throwing up the earth regularly on either side in a straight line for a length of about ten metres and seventy centimetres deep; starting from the lower end of the conductor towards the water pipes leading to Ferentino, crossing a wall, and considerably damaging the corners of the building. (2) It followed the line of piping, destroying it and driving some of the fragments to a distance of nearly eighty centimetres, the lead in the pipe-joints being melted, and the water of course, ceasing to flow towards Ferentino, spread itself over the building. (3) Another portion of the fluid, passing on to the pipes leading towards Alatri, crossed a reservoir, driving out with force some wooden plugs, passed then into another reservoir situate in the town, twisting in a most extraordinary manner, a sheet of lead, and then, having committed other damages, escaping by the feed-pipe of a public fountain. (4) On examining the point of the conductor it was found to be blunted, and it was impossible to unscrew it. This point was melted in such a manner for a length of three centimetres that its diameter at the end, which seemed to have been cut short off, was only one centimetre. The gilding had almost entirely disappeared. The church itself was not, however, in the slightest degree injured.

What strikes us first of all in the foregoing is the large quantity of the electric fluid which must have been present, and the immense force of its discharge. It does not, however, appear that the ploughing of the trench from the bottom of the conductor can be attributed to any direct action of electricity. We incline rather to assign it to the sudden expansion of the moisture contained in the soil ; and it should be remembered that Arago is of opinion that this moisture is also the cause of the scar or mark which is noticeable from the top to the root of trees struck by lightning. Secchi follows out the same idea with reference to the rupture of the pipes, which he considers attributable to the sudden evaporation of the water in them, and not to any mechanical action of the fluid. This theory does not, however, appear to us satisfactorily to account for the melting of the lead in the joints. Looking at what occurred in the conduit leading to Alatri, the same distinguished philosopher considers it still more remarkable. He observes, first of all, that the small interruption of continuity between the pipes and the reservoir must have given rise to a leap of the fluid, and consequently to an explosion of vapor, which would account for the deformation of the sheet of lead ; and from this he draws the conclusion that the distance, some two hundred metres, intervening between the lead and the building, was not sufficient for the fluid to lose itself in the earth. In fact, the quantity of electricity discharged must have been enormous, for it travelled, marking its passage, a distance of upwards of three hundred metres from the conductor. True, however, that the storm took place after a long period of drought, when, consequently, the soil was in a state but ill-fitted to favor the dispersion of the fluid.

Pursuing the same subject, we find that M. Jaspar, a manufacturer of lightning conductors at Liege, narrates a similar case, which occurred at a chateau in the neighborhood of that city. In this case the wire of the conductor passed against the wall of a lavatory, on the other side of which, exactly opposite to the conductor, was a tap for drawing water which came from a spring some three or four kilometres distant. The lightning hit the conductor, but the fluid, instead of following it down into the well in which the end was plunged, passed through the wall, and struck the pipe on the other side, without however, doing further damage than displacing a few bricks. M. Jaspar, who at the time of fixing the conductor was unaware of the existence of the pipes, cock, etc., on the other side of the wall, offers the following explanation: The well, he says, was probably dry or nearly dry at the time—a suggestion, however, as to which no confirmatory observation was made at the time—while, on the other hand, the cast iron pipes, with metallic joints, sunk n the earth, formed a most excellent means

for dispersing the electricity, and the fluid, as is always the case, quitted the bad to follow the good conductor. It would appear from the foregoing that it is absolutely necessary that communication should be established between lightning conductors and any neighboring masses of metal, especially with water or gas pipes, and also that the greatest possible surface for discharge should be made available. This surface in the conductor of F. Secchi, of which he wrote, was certainly greater than that which Matteuci deems sufficient for the discharge of the conductors of telegraphs, but, as we have seen, it was far from sufficient. Examples of similar actions of lightning to these are not rare in Italy, and Father Secchi mentions the case where the steeple of the church at Lavinia was struck, and the bell melted in such a fashion that the metal ran like hot wax; still he does not consider that this rupture ought to be attributed to any mechanical action of the lightning in the strict sense of the word, although at the same time he admits that the bell, in consequence of the heating of the points through which the electric fluid passed, was subjected to a sudden expansion—an expansion which the surrounding particles could not instantaneously follow, and which hence produced a fracture from almost the same causes as when a glass vase is touched with a red-hot iron. The last point to which he wishes to draw attention is, that as the accumulation of electricity in metallic bodies is in proportion, not to their bulk, but to the area of surface, it is necessary to place not only the gutters in communication with the conductors, but also with the bands of zinc which are frequently used to cover the hips of the roofs; in proof of which the following:—

On the evening of the 26th July, 1870, says M. J. Muller, of Fribourg, during a severe storm the lightning struck a large three-story high building, on which were some reflective conductors. Two of these were placed at the extremities of the ridge of the roof, and united together by a bar of iron, from the centre of which the conductor started, which, after having been prudently placed in communication with the gutters, was carried down to the ground. These gutters were furnished at different points with descending pipes for carrying off the water, which reached almost to the earth. The ridge as well as the hips were covered with bands of zinc, on which were immediately placed the stalks of the conductors; but there was no communication established between the bands of zinc and the pipes, nor between these and the ground, and in this lay the defect. So long as lightning finds substances which are good conductor, such, for instance, as bars of iron, it follows them without doing any harm, and it is only when leaving their extremities to seek for other conductors that disastrous effects result. Thus, if the communication we have pointed out had been made, it is easy to imagine that on lightning striking the conductors, the fluid would have been carried to the ground, without causing any damage. But this not being the case, an explosion, in the event of the tension of the electricity becoming sufficiently great was to be expected; and in fact this is what actually did occur on the night of the 26th of July, 1870, when the metallic band was torn in different places, as was also the lower end of the pipe. From this pipe the fluid passed in succession to those for gas and water, breaking them both. A report on this subject was prepared by M. Muller, who pointed out the absolute necessity of establishing communications between the gutters and the bands of metal on the ridge and hips of roof, and also between the descending pipes and the earth. Unfortunately, no attention was given to his warning, although many buildings had conductors deficient in the very ways he pointed out; but the neglect was punished, for on the morning of the tenth of May last year, the lightning under almost similar circumstances struck the buildings at the railway station, Fribourg. The horizontal bar joining the two conductors was shivered, the sheet iron coverings on the hips of the roof and the descending water-pipes were torn and broken; and we have, therefore, another instance of the great necessity for communications being established between the metallic coverings—where these are used—of the ridge and hips of the roof and between the descending water-pipes and the earth, even in those cases where there are no lightning conductors on the building. It is true that in England such accidents are comparatively rare; it is not, however, more than three years back since the tower of a church—St. Saviour's—in the very heart of the metropolis was so struck, and one of the pinnacles knocked off, besides other damage being done; and certainly no

single year passes without something of the sort taking place. The part of the foregoing which, however, appears to us the most important to the bulk of our population, is the necessity which is insisted on of the pipes from the roof gutters being placed in communication with any metal on the roof or in the gutters themselves, and that they be carried down to the dead earth. We think ourselves that this last is the condition of safety most frequently violated, for one has only to notice the rain-pipes as one walks along the streets to have tangible proof that their being carried down into the ground is the exception rather than the rule, and this especially in the suburban neighborhoods. To landlords and builders, then, we especially recommend attention to what we have written. Large public buildings are probably in most cases fairly well protected; but, as we have said, where the rainwater-pipes are the only conductors on a house—and to some extent they are sufficiently effective ones if properly placed—it should be recollected that they should *always* be in communication with any metal on the roofs, and still more should they *always* be in distinct communication with the ground, and not cut off, as is too frequently the case, some foot or so from it.

LIFE-SAVING GEAR.

From the "Nautical Magazine."

A question forcibly engaging the attention of persons interested in ships and seamen at the present time is, whether all sea-going ships should not be compelled by law to carry an increased number, and a superior description of life-buoys, and increased boat accommodation, or other increased or improved means of saving life at sea in emergencies. That this question should command attention now is not to be wondered at. We have endured the agitation consequent on Mr. Plimsoll's well-meant and vigorous book; we have also had harrowing scenes and lamentable loss of life consequent on serious marine disasters; the wreck of the steamship *Atlantic* with a loss of 535 lives; the running down of the *Northfleet*, when peacefully at anchor in a well-known road-stead on our coast, and a loss of 293 lives, and, more recently, the loss of the *Ville du Havre*, a transatlantic steamer that, in defiance of all law and reason, got into the way of a British sailing ship, the *Loch Earn*, and was run down, with a loss of 226 lives. That many of the 1,054 lives lost in these three casualties might have been saved, had there been sufficient suitable, available, and efficient life-saving gear on board, there is no room for doubt. This being so, the fear we now have is not that improved and additional, and even excessive means for saving life will not be provided, but that patentees and ingenious persons will "improve the occasion" with a view to forcing particular inventions on the attention of the public, and that the Legislature may be pressed and unduly pressed, to require that some special invention or arrangement shall be adopted in all ships; and it is because no one invention or arrangement for saving life at sea can be applied indiscriminately to all classes of ships, and to all voyages, that we should at once endeavor, in a calm and quiet way, to inquire whether calamities at sea cannot be classified in such a way as to furnish an indication of the most likely means for saving life in various classes of voyages, and various descriptions of ships and casualties.

To put a case, by way of illustration of the belief that one form of life-saving gear is sufficient, we have only to point to the general impression existing that rafts must always afford a valuable means of saving life at sea. That rafts, even improvised rafts have saved life, there can be no question; but before we can place the raft in a foremost place of saving life in all cases, we must not overlook the circumstances in which they have generally been efficient. We shall then find that fine weather or comparatively fine weather, and sufficient time for launching and stowing, have generally been important elements in the success. Let however, an attempt be made with a raft to save life in a cold climate in the winter, and in a rough sea and far from land and the result would be altogether unsatisfactory. Means that are efficient for saving life in the Pacific, in a beautiful and favorable climate, would be absolutely

worthless in Atlantic winter gales, and would become a means of prolonged torture. Means that would be ample for home trade ships would be of but little use in foreign-going ships, and means necessary for foreign-going ships would be altogether out of place in our coasters. In short, the nature of the voyage or employment of the ship, in the matter of saving life, as well as in the load line, is one of the first points to be considered; the next point is the number of hands, the next the condition of the ship, and the next her construction. For, just as means that would be efficacious in the Pacific would be of but little use in the Atlantic, so certain means for saving life in a small or weak coaster are necessary that are not necessary in large and strong ships; and when the means provided have to be applied, they have to be applied in a different manner and under different circumstances and conditions, in the various classes of ships.

The cases in which means are required to be used from on board ship to save life may be broadly classed as follow:—

1. A man overboard.
2. Assistance required by another vessel at sea.
3. The gradual and steady settling down or destruction of a ship in comparatively smooth water.
4. Sudden and great emergencies, such as being run down, striking on rocks, &c.—*Ville du Havre*, *Atlantic*, &c.
5. Strandings on a lee-shore, as in the case of the *Royal Charter* (loss of 446 lives), *Royal Adelaide*, &c.

The means carried within the ship herself of saving life may be classed as follows:—

1. Life-buoys.
2. Life-mattresses.
3. Life-jackets or belts.
4. Deck-seats, and other movable buoyant contrivances, or articles carried on deck.
5. Ordinary common boats.
6. Common boats rendered buoyant as lifeboats.
7. Lifeboats.
8. Rafts.

Having made a general classification of the cases in which means are ordinarily required, and of the means ordinarily provided, we now have to consider which of the means are best adapted to the various cases.

Before we enter on this part of our subject, we must, however, state in plain terms that we are advised, and believe, that in the case of ships carrying a large number of passengers in rough and dangerous passages, or in much frequented seas, it is impossible to provide means for saving all the lives on board in most of the ordinary circumstances attending a casualty. In the mid-Atlantic, for instance, it would be impossible in winter to preserve the whole, or anything like the whole number of passengers, for any considerable time after a foundering where no other ship is near; and even if the passengers could be placed on rafts, they would be without a supply of food, water, and clothing, and would probably succumb to cold, hunger and thirst. We mention this at once lest it should be supposed that in afterwards stating that certain means might be efficacious in certain cases, it should be inferred that we believe that loss of life at sea may be very materially prevented in great wrecks or strandings, or in the case of the numerous "missing" ships from which at present not a soul survives to narrate the cause of loss and the sufferings of the crew.

The first case in which an appliance is wanted on board ship that we shall refer to is, that of *a man overboard*. The readiest and best means of assistance in such a case is the life-buoy; but it should be capable of floating high in the water, and be of light color, so that it is easily seen by day, and it should at night be thrown over with one of Holmes's lights attached. These lights float on and actually burn the water as fuel and last for forty-five minutes. We may accept the life-buoy as the first means to be used. The Board of Trade have issued instructions that no buoy is to be passed as a life-buoy that does not come up to their standard. This is a step in the right direction, as the rush and cork-shaving contrivance, formerly in vogue, were worse than useless. We, however, doubt whether the proper form of life-buoy has yet come into use; but we have recently seen some that are under trial, and will, we believe, supersede most others. The life-buoy should never be made fast to anything, but should be hung with a becket and slip toggle, and a proper supply should be carried in passenger ships, and two in every other ship. The life-buoy is of value just in proportion to the speed with which it can be thrown over. But as regards life-buoys, the question naturally suggests itself, why should there not be a large and light buoy in which

a man could jump over, a buoy that might serve as efficiently as a boat? The only difficulty is in finding a material of which such a buoy can be made. When a suitable material is found, the difficulty vanishes. Something light and, at the same time, practically indestructible is wanted. Before we pass from the subject of the life-buoy, it is well to state that any contrivance that requires inflation, or pulling out, or stiffening before it is used, is altogether beyond serious consideration. Anything to be used as a life-buoy must be kept as it is to be used. We may concede that the life-buoy is the first means for use in case of a man overboard, or a boat capsizing alongside, &c., and that it is, if properly constructed, well fitted for the purpose, and that all ships ought to carry them.

Life-mattresses are the next contrivance for consideration; and as the attention of several practical men has been devoted to them, they require more than a passing notice. Some of these mattresses are exceedingly good in design; for instance, those of Admiral Ryder and Capt. Forster. Others are bad. But, our objection to mattresses as a universal remedy for loss of life at sea is, that they are not calculated to meet sudden and great emergencies, as they must be kept below one or two decks in passenger ships; and that when the emergency is not sudden there are other and better means of saving life. In coasters, with few hands and in ships of the Royal Navy where there is discipline and cleanliness, these mattresses would be valuable. But, on the other hand, where means are most wanted they are unsuitable.

In the case of the *Atlantic*, the master stated. "The first intimation I had of anything was the ship striking on Marr's Rock. The officers were quickly at their stations, accompanied by the quarter-masters. The first sea swept away all the port boats: and the ship heeling over rapidly soon rendered the starboard boats useless. Every effort was made to send the people forward outside the ship; but the short time defeated all our efforts. A lifeboat rolled over in a few minutes, carrying with her thirty or forty men. Communication was at length established by a rope with a small outlying rock, forty yards distant. The largest number of saloon passengers lay near the main-rigging, and died. We encouraged, as much as we could, about 450 people on the ship's side to keep moving about. In many cases they gave up entirely, and died apparently without pain. Twelve men, clinging together, lay down beside me, and notwithstanding all efforts to rouse them, died and slipped off into the sea." This sad case is about the best illustration we can give of the combined effects of fear and cold; and it also shows the utter uselessnes of boats in such a case. The hold was full of water, and even if there had been cork mattresses below they could not have been reached.

As regards the *Ville du Havre*, one of the reporters stated:—"The chances of saving life would have been extremely small even in the daytime, with possibly a large proportion of the whole number of those on board upon deck; but at two o'clock in the morning, with almost every soul except the watch asleep below, these chances were reduced to the minimum. Besides, as our information tends to show, a large quota were women and children, with whom it was almost physically impossible that they should in the brief space allotted to them, have reached the deck. One of the cabin passengers is of opinion that fully three-fourths of those who occupied the handsomely-furnished saloon of the *Ville du Havre* were women and children. Of the 226 who were lost, it is thought that by far the greater portion, probably five-sixths, never came on deck." "It was only" says one passenger, "when I came up again from the bottom that I noticed any cries. Then I heard a great many persons, who were struggling in the water, crying out piteously for help." Another says: "The bulk of those who were picked up were found floating on the ship's steps or ladders, rafts, pieces of broken yards, fragments of the bulwarks, or timbers of the ship, which they caught just as the vessel passed below the waves, or had enough of consciousness and strength to seize after coming again to the surface." Another says: "Nothing could have saved you except holding firmly by some piece of wreck or life-belt; and most of those on board, I am sure, never came on deck." Another says: After being in water a few minutes I got hold of a buoy, which enabled me to keep afloat for nearly an hour, when I was picked up by one of the *Loch Earn's* boats." And, lastly, another says: "When she was struck, the passengers, as I said, came rushing up from below and began to fill the boats. There were about fifty of them in one of the long-boats

when the mainmast fell on it. Some of them were killed right out, some had their heads smashed, others had their arms and and their legs broken." And, finally, as illustrating the uselessness of the boats in such a case, the French official report states that, "Nothing remained but to save the greatest possible number of lives by means of the boats. The two lifeboats which were on the tackles were the only ones which could be rendered rapidly available; of the six others, two had been smashed in the collision; two more were crushed by the fall of the mainmast and the mizen; finally the last two could not be disengaged in time."

Let the reader think of the confusion and disaster attending sudden calamities in public buildings ashore, the burning of a church or a theatre, for instance, and how persons are crushed, and suffocated, and trampled over in getting to the doors, even when unencumbered by having to convey anything away, and then let him picture to his mind the attempt of hundreds of people, not to rush to doors on a level, or to rush down the gallery stairs, but to rush up a ladder and through a hatchway; and that the attempt is to be made not by persons ready dressed and fully awake, but by people suddenly roused from sleep in a comparatively dark hold. Let the reader think of the suddenness of these wrecks and collisions, that the majority of the passengers are in their berths, and that even to get on deck unencumbered is a great effort, and that the passengers' berths are arranged in tiers one above and behind another. That to get out of bed at all, the majority of passengers would have to climb over others; and then let him think what would be the magnitude of the difficulty if each passenger were to attempt to ascend the companion-ladder carrying his bed. A more complete way of preventing egress from below could not well be devised. It is not too much to say that if the passengers took up their beds many would be killed in frantic endeavors to reach the deck, and that the ship would go down with most of the people below. Our conclusion is against floating-beds, and against any contrivance that has to be kept below and conveyed from below in a sudden emergency in passenger ships. It will either be left below, in which case it need not have been provided, or the finding and securing and bringing of it up will lead to delays and dangers worse than many existing at present. For coasters, however, stranded on a lee shore, or for ships other than passenger ships, especially in cases of collision where one ship stays by the other, these mattresses might enable the crew to take to the water with confidence; but then the question of course arises, are mattresses the best means? This will always be a matter on which opinions will differ, and we should be but too glad if those seafaring men, who discover advantages in cork mattresses, would take the practical step of putting them on board their ships, and seeing that emigrants provide their own beds: there is nothing but cost to prevent them from providing themselves with floating-beds if they choose, and for a floating-bed nothing equals that of Admiral Ryder, made by Messrs. Burt, of Dock Street, London.

Life-jackets and belts are the next appliances we have to consider. Under this head we include all inventions and appliances intended to be attached to the body before taking to the water; we may, therefore include with them, neck rings and chest or back bottles.

Life-jackets are required by the Board of Trade to be provided for the crews of the life-boats carried by passenger ships. The crew manning a life-boat ought certainly to have life-jackets; here, then, is a legitimate use for the life-jacket—and the best, if not the *only* life-jacket for this purpose is that of Captain Ward, R. N., the Chief Inspector of life-boats to the Royal National Life-boat Institution. But, beyond the use of life-jackets for crews of boats, their advocates, like the advocates of mattresses, claim for them an extended use. In the first place, an efficient life-jacket may be better than a life-buoy for a man jumping overboard to save life. This may be conceded; but we then have to come to the further question of providing life-jackets for all the passengers and the crew. The patentees of inventions of this sort, and many persons whose desire to do good is greater than their powers of judging how to do it, will advocate the providing many means for saving life on board ship. Let us, therefore, think for a little on this subject of life-jackets. First, as we have already stated, we do not believe in any means of saving life in great emergencies that is stowed below decks; the only exception to this is, of course, when the means used become, from a close contact with, and fas-

tening to the human body, almost a part of the body. If a life-jacket is to be provided for every passenger, it will be useless in great emergencies, unless the passenger is content to sleep in it, and in that case a cork-mattress would be unnecessary. As regards life-jackets, all those things that require to be "inflated" before they are put on, are of questionable use, although they would be the only things of the sort fit to sleep in. The emigrant's bottle, intended to be strapped on the chest, is more objectionable than the worst form of life-jacket. It would be impossible to sleep with it strapped on, and "to empty out the water, fasten in the cork," and strap on the bottle, in an emergency, would generally be impossible, and, when not impossible, the bottle when on is likely to slip low down round the waist, and expose the wrong part of the body above the water; but, besides this, the presence of the bottle in front of the emigrant would effectually prevent him from assisting infants.

A neck ring made of ox gut, or some such material, and of about the size of a German sausage, was exhibited at the Lord Mayor's *Northfleet* show of models in London, and appeared to be sufficient to keep the head of the wearer above water; but to be of use, it must be worn and slept in at night. It would generally fail in great emergencies, unless worn. Trusting to safety by laying hands in the dark on and then blowing out and then fitting the neck into, a sausage skin, in dire confusion, would be disastrous. When life-jackets *can* be used, is when they are kept on deck ready, and when the persons wanting to use them are on deck and ready to take the water, or can be got quickly on deck. Where their attempted use would end in failure, would be in great disasters, where numerous passengers are below deck at the time of collision or wreck, and where they would either not have time to secure their life-saving gear, or, having, secured it, would be unable to get on deck with it. The cases of the *Captain* and *Atlantic* will illustrate this. We do not, therefore, look for any great saving of life in large and sudden wrecks from the use of life-jackets, or cork-beds; but we do think for coasters and ships not carrying passengers, Captain Ward's life-jackets will be of use and they must be carried.

Deck-seats and movable gear on deck are the next appliances we have to touch on. Under this head we may include all light, or comparatively light, buoyant contrivances—deck-seats, life-buoys, hen-coops, &c., &c. For coasters and ships other than passenger ships, except in very sudden emergencies, we set no store on these buoyant deck articles, for the reason that, where the number of persons on board is much below, or at all events not in excess of, the boat capacity, a good lifeboat is the best, safest, and most comfortable of all means for saving life; and vessels that do not carry passengers can, as a rule, get their boats down and their crew into them. For passenger ships, however, we know of no means so likely to be effectual in sudden disaster as buoyant deck gear. To illustrate our point we have only to refer to the *Northfleet* and *Ville du Havre* casualties. The official report on the loss of the *Loch Earn* states as follows:—"While inquiring into the particulars of this fearful catastrophe, and the terrible sacrifice of life, the attention of the Court has been directed to the fact of the rescued persons, eighty-seven in number, having been saved mainly by means of the floating *dèbris* of the wreck. The Court would therefore suggest, for the consideration of the Board of Trade, the great desirability of multiplying the means of escape afforded by the floating objects, and the question whether it might not practicable to render the deck-seats or other appliances available as life-preservers by the adaption of the air-tubes or other means tending to so important an object."

This deck gear is, of course, of use only in sudden catastrophes, and then only for a limited time—for such a time, in fact, as will enable passengers to keep afloat until assistance, if moderately near, can be rendered, or until they perish with cold or exhaustion. What is wanted in a sudden emergency, like the *Northfleet* collision, is a quantity of smallish detached buoyant articles on deck, and widely distributed, so that every passenger has a fair chance; rather than one or two large rafts. There is no time to man and lower all the boats, or to get passengers into them; and if they do get into them they are still often killed or drowned. The case of the *Northfleet* furnishes also conclusive evidence that buoyant contrivances that would float off the deck, and could be grasped by struggling passengers, would have been of use. This, case like the cases of the *Alantic* and

Ville du Havre, quoted on page 160, also shows how lamentably boats fail in emergencies. The official report says: "Orders were then given to clear away the boats, and to take the women and children. The lifeboats were forcibly seized by a number of the male emigrants; the port boat was lowered, and shoved off with thirty of them, without a single seaman, without plugs, and only one oar and part of another. No one knew how to manage her; she filled with water, and her inmates shouted loudly for assistance. Others of the emigrants seized the starboard lifeboat, and a struggle ensued between them and a part of the crew for its possesion; eventually, it was partly cleared, the captain's wife one other female, two children, six seamen, and nine of the male emigrants were in her. In lowering her, she got stove by the main sheet bolt, and filled with water. The captain, hearing that she was in a sinking state, ordered the boat's crew to pull off to save their lives. An attempt was made to clear away the remaining boats; their lashings were cut, but before they could be freed from the skids, the ship suddenly foundered (about thirty-five minutes after she had been struck) with her living freight her anchor-light burning brightly when she went down. . . . The steamtug *City of London* (Samuel Kingston, master), was also at anchor the same night, about a quarter of a mile to the westward of the Roar Buoy. At half-past ten rockets were seen to go up to the eastward, about two miles distant. The master at first supposed them to be a signal for a pilot; but subsequently, at seeing others go up in quick succession, believed them to be signals of distress. He at once weighed anchor, and steamed towards the spot, which occupied about half an hour, and when within a cable's length of the ship he saw her go down. The tug was surrounded by people struggling in the water for their lives, and some few were hauled on board. The starboard lifeboat of the *Northfleet* came alongside, partly full of people, who were all taken on board. The mate of the tng and some of the boat's crew put back in the lifeboat, though full of water, with the thole-pins broken, and picked up four other persons from the sea. Subsequently, one of the boats of the *Princess*, pilot cutter, brought four more men, whom she had picked up, and put on board the tug, making a total then on board of thirty-four lives. The pilot cutter, the *Princess*, of Deal, was cruising off the Dungeness of that night; and, on seeing the signals about two miles distant, beat towards the scene. On her arrival, however, the *Northfleet* had foundered. The master of the cutter lowered two boats; the first was manned by the mate (John Stanley) and three seamen, which was sent to the neighborhood of the wreck; the second boat, manned by the steward and three pilots, was sent to cruise about and render assistance to any one floating about. The first boat, after great difficulty, rescued ten men from the mizen cross-trees, which were about 10 feet above the water; they were taken safely on board the pilot cutter. The boat made a second trip, and rescued five men from the main crosstrees; and, in a third trip, rescued six more from the fore crosstrees, making twenty-one souls, including the pilot, Mr. George Brack. . . . ." The only chance is to take the water, and trust to some buoyant object. We have already explained why, in our opinion, life-saving gear carried below deck is not likely to be of use in such a large disaster; we must now point to the difficulties attendant on stowing it on deck. In the first place, any gear so stowed must be secure against heavy seas, and must at the same time be so arranged as to be capable of instantaneous disconnection when wanted. In the second place, it is liable to destruction, as is explained under the head of boats. There is, however, no reason why deck-seats. instead of being almost useless from a life-saving point of view, need not be almost as useful as boats. Nor is there any reason why many things on deck need not be buoyant of themselves. In the "Collins" line all deck-seats were as buoyant as life buoys. But there is a further point. Why should not loose buoyancy be carried in addition to deck-seats and other similar things on deck. Our attention has just been called to a little thing called a "save-all," which we should like to see tried. Sufficient for saving 300 persons can be stowed in a locker, or specially constructed deck-house of 6 feet by 6 feet. Distributed among smaller lockers about the ship, or stowed in the boats, they could be at once used, or, if they were not secured by passengers before the ship went down, they being the first things that would float wide-spread among the passengers, would afford the readiest security for keeping

above water. Shape, no less than buoyancy, is an important element in constructing life-saving gear. We are now, of course, speaking not of saving passengers with boats and a supply of provisions, and conveying them away from the wreck, but simply of the means of keeping all passengers afloat as long as they will live in the water. Such appliances as these, though good for passenger ships where assistance is at hand, would, as we have before said, be useless where no assistance is at hand, and would be unnecessary in ships other than passenger ships provided with boats, and free from the confusion attendant on the presence of frantic women, children, and landsmen.

Ordinary common boats are the next appliances we have to notice; but as these, when carried in large ships, are generally only wanted for ships' use, and, if wanted for passengers' use, are now, as a rule, useless in emergencies, we may dismiss them with one remark—viz., that no boat having a square stern ought to be carried on board a merchant ship, if it is ever intended for use in saving life in bad weather, The Board of Trade will not pass square-sterned boats for lifeboats in passenger steamers, and it would be wise for boat-builders and shipowners to throw over old patterns of square-sterned boats, lest some day they find a useless stock on hand.

As to the means of rendering a common boat buoyant, after the manner of a lifeboat, we have to say, first, that for a ship's boat, solid or granulated cork, or any other solid substance, is just so much dead weight or lumber in the boat; air spaces alone are fit for buoyancy. The Royal National Lifeboat Institution wisely use cork in their boats where it serves chiefly for ballast. Air-casings made of zinc are, of course, wholly inadmissible, and copper is expensive and heavy, and unless covered over with wood is liable to damage. We are only aware of one material that is fit for air casings, and that is a combination of cork between two layers of canvas. For the present, we can only observe that there is no practical reason why a common coaster's boat should not be rendered buoyant, and, for her purposes, as valuable as the best lifeboat. The only thing wanted is the starting of an establishment in which the cork and canvas apparatus could be manufactured quickly, and at such a low price as to bring it within the means of the poorest shipowner. There are no patent rights preventing the use of this combination.

Lifeboats are the next means, and are, of course, the best where they can be used. We are not now alluding to sham things with mock wooden air cases, or rotten zinc or heavy copper tubes, but to really well and substantially-built boats. Messrs. White, of Cowes; Messrs. Forrestt, of Limehouse; and Messrs. Woolff, have built some very fine wooden boats, and the Hamilton Windsor Iron Works have built fine metal boats; but the time has come when we must consider whether good and efficient and insubmergible boats must not be the rule instead of the exception, and whether in this matter of lifeboats for ships we have not been going on the wrong tack altogether as regards efficiency. The fault we find with all lifeboats yet constructed for ships is, that the buoyant apparatus is carried inside the ordinary lines of the boat, whereas a part, if not all of it, ought to be outside. It stands to reason that any buoyant apparatus inside a boat is so much weight, and that it cannot assist in giving lateral stability; and further, that it is of no use until the boat herself is filled, or partly filled with water. Buoyant apparatus is of no use while it is in the air inside a boat, but let it be in the water and it is of use at once. Solid cork puddings or buffers have been used outside boats, but they are not of much use, as their weight alone tends to immerse the boat. What is wanted is a boat with the air buoyancy so far outside as to be of use at once, and so arranged as to give lateral stability. A lifeboat is not wanted to sail a match or to row a match, but is wanted to carry very great weight in the worst weathers, and to be free from the danger of capsizing. We do not hesitate to say that no boat in which the buoyancy is inside the ordinary lines is free from the danger of capsizing. All passenger ships should have lifeboats of the very best model, and all foreign-going ships should render their long boat buoyant as a lifeboat, which can be done effectually at a trifling cost. We regard collapsible boats and rafts and contrivances that require inflating as something wholly beyond serious consideration.

Rafts.—Mr. White, of Cowes, has a bridge-boat, and latterly we have seen

several other contrivances for using the upper part of a bridge or the top of a deck-house as a large pontoon raft; but none of these we have seen yet can, as well as being readily let go, be also securely fixed against the action of heavy seas. The floating off of a whole deck-house as a raft or "ark" has over and over again been proposed, but nothing really practical has come of it. For rafts we are therefore at present reduced to those that must occupy boat space. The best we have seen is the lifebuoy boat designed by Captain Murray and Mr. Gray for coasters; but seeing that it is impossible for steamers to carry more boats than they do at present, the question yet remains, how far rafts ought to be carried in addition to boats. That they might with advantage be carried in lieu of some of the present boats is on all hands admitted, but the difficulty for owners to settle is what form of raft to carry, and how to stow it. No one can, for a moment, doubt that really efficient lifeboats and really efficient rafts would sometimes materially assist in saving life, because they would not hurt by being stove. Common boats can never be of immediate and great use in exceptional cases like the *Ville du Havre*. A raft, of course, can have the advantage over a lifeboat, that, whichever way it falls in the water, it turns up right; it has also, if properly constructed, the advantage over a common boat, that it will not turn over: but a good lifeboat, constructed on the plan we have suggested, has one advantage over everything else for ordinary purposes, and that is, that it can carry in comparative comfort all the persons it takes on board, and that passengers in an insubmergible and well-appointed lifeboat might find shelter and protection from sea for a longer period than they could get by anyother appliance for saving life.

Our practical conclusions are—

1. That for coasters, and short over sea trips, two good lifebuoys, a life-jacket for each of the crew, and buoyancy in a boat or in a raft, are all that is necessary.

2. That for foreign-going ships, other than passenger ships, instead of the four, five, or six, or seven boats they are now required by law to carry, on or more good boats, with sufficient buoyancy, and one or more good rafts, according to the size of the ship, two or more lifebuoys, and four life-jackets are sufficient. At present they and coasters are alike required to carry boats according to their tonnage.

All sailing ships, not carrying passengers, are required by law to carry boats as follows, viz.:

Under 100 tons register	1 Boat=14x5x2.2ft.
Above 100 and under 200 tons register*....	1 Boat=14x5x2.2 and 1 Boat=16x5.5x2.75
Above 200 and under 400 tons register.....	1 Boat=14x5x2.2 and 1 Boat=20x6x3
Above 400 and under 600 tons register.....	1 Boat=16x5.5x2.25 and 1 Boat=22x5.5x2.5 and 1 Boat=22x6.5x3.25
Above 600 and under 800 tons register.....	1 Boat=16x5.5x2.25 and 2 Boats=24x5.5x2.5 and 1 Boat=25x7x3.5
800 tons register and upwards.....	1 Boat=18x5.5x2.25 and 2 Boats=24x5.5x2.5 and 1 Boat=26x8x3.33

All steamships, that do not carry passengers, are required by law to carry a full complement of boats, the same as steamships carrying passengers. Thus, an ordinary steamship, say of 1,000 tons, carrying merchandise, and not carrying a single passenger, is required by law to carry seven boats. These seven boats are as follows One boat of $18 \times 5.5 \times 2.25$, $\times$ 2 boats each of $24 \times 5.5 \times 2.5$, + 2 boats each $22 \times 5.5 \times 2.5$, +2 lifeboats each 28 feet $\times 8.5 \times 3.5$: or they may substitute a launch $27 \times 8.5 \times 3.3$, for the two boats of 22 feet long.

The evidence on the subject of boats, given by the (Marine) Assistant Secretary to Board of Trade, is as follows:

Question "10,554 (Mr. Rothery). You know the 294th Section of the Merchant Shipping Act, which says, "No officer of Customs shall grant a clearance or transire for any ship hereinbefore required to be provided with boats or life-buoys unless the same is duly so provided?"—Yes.

"10,555. Did you call upon the Customs to enforce that clause?—About five years ago the Customs were called upon to enforce that clause, and they sent out a circular to the collectors, and tried to enforce it.

"10,556. What was the result?—The result was that the whole trade was stopped.

"10,557. Actually stopped?—Actually stopped."

"10,559. The Customs advised you that it could not be enforced?—They did."

* In sailing ships, not carrying passengers, of 150 tons register and under, a substantial boat of sufficient capacity may be substituted for the two boats named.

Instead of all the boats required by law, it would be wise to have boats and rafts with *buoyancy* sufficient for the crew.

3. For passenger ships, it is probably wise to provide additional buoyancy of the "save-all," or life-preserving class, safely and securely stowed, with a view to meeting sudden calamities; a few good lifeboats that will not turn over, and a few good rafts or deck-house roofs for casualties that are not sudden. The boats should be carried at davits, and the rafts at davits, or conveniently elsewhere; but, as to the number of boats, it is impossible to provide more accommodation than at present.

In conclusion, it is well to bear in mind that gear carried on deck is liable to destruction before it can be used; such is the force of the sea in the Atlantic trade, that the boats in the chocks above the decks of large steamers, high up out of the water, are sometimes broken to matchwood, and that, although life-saving gear to be of use in emergency must be carried on deck, it is exposed to destruction in some trades, and may therefore be of but little use. Another point is, that to cumber the deck with appliances is to lead to danger by causing difficulties in navigating a ship. The providing of life-saving gear is, after all, not so simple a subject as many inventors and humanitarians would make out.

BOILER EXPLOSION AT THE LINTHORPE IRON WORKS.*

The author commenced by referring to a paper he had read at the meeting of the Institute held at Merthyr-Tydvil in September, 1870, upon "the efficiency and durability of plain cylindrical boilers." He had then pointed out that one-fourth of all insured boilers were of the plain cylindrical type; that they continue to be preferred by many engineers, and especially for the utilization of the heat, derived from the combustion of blast furnace gases; and that they were specially liable to danger from "seam rips." He had shown that one great cause for this arose from their being usually suspended rigidly from more than two supports; and had proved by a long series of experiments upon pieces of boiler plate, alternately heated and cooled like the bottom of a boiler, that a permanent contraction of the latter must always eventually ensue, causing a seam rip and possibly an explosion. As an antidote, he had advocated the suspension of long horizontal boilers upon volute springs, which would permit a change of form according to alterations of temperature, without materially relaxing or increasing their support. Since that time he had had three boilers, so mounted, work with marked success, but the experience derived from them had led him to further improvements. During the same interval many boilers rigidly mounted had also been at work; and one of these recently exploded at the Linthorpe Iron Works, causing great damage, but fortunately no loss of life. It was because he considered all such boilers unduly strained, and in constant jeopardy, and because he thought he could now show the way to make them perfectly safe, that he ventured to call renewed attention to the subject. Some owners of steam power objected to be involved in any public discussion of the details of a disaster which might have befallen them. Messrs. Lloyd & Co., on the contrary, at once yielded their cordial consent to the proposal, that all possible experience should be derived by the members from their misfortune; and gave the writer *carte-blanche* to visit, and examine their steam machinery, and to investigate the circumstances attending the explosion; and at the same time expressed an earnest desire to adopt improved appliances if only such could be found. The exploded boiler was insured with the Midland Steam Boiler Inspection and Assurance Co.; and Mr. E. B. Marten, their chief engineer, had referred to it in his last annual report as having been caused mainly by changes of form, owing to unequal expansion, in conjunction with a rigid system of suspension. Although this evil was coming now to be generally recognized, no one seemed disposed to take precautions to obviate it, except in one or two cases, where altogether novel types of boilers were adopted; and in one or two others, where it was sought to strengthen

*Abstract of a paper read before the Members of the Iron and Steel Institute, by JEREMIAH HEAD, of Middlesbrough. From the "London Mining Journal."

the boiler by making the bottom plates of Low Moor iron. But at most of the new ironworks, long plain cylindrical boilers were still being placed upon more than two rigid supports. The author then proceeded to explain a model showing the method of suspension and various other appliances he advocated. The boiler represented was 80 feet long, by 4 feet 6 inches diameter, upon five supports. The second and fourth of these were rigid, giving the boiler a constant average height relatively to the brickwork, while the first, third, and fifth, were yielding. This was effected by substituting levers and balance weights for simple suspension rods. Each pair of levers supported one-fifth of the weight of the boiler, whatever form it might assume. In the model, the boiler was actually divided into five sections, jointed together. Along the bottom in a groove was a steel rod 3-16 in. in diameter; one end of this was screwed, and worked in a nut in the fifth section; and near the other end was a collar, working between two guides, secured to the first section. The rod passed also through guides attached to each of the other sections, and upon its front extremity was keyed a small hand wheel. By turning the latter to the right or to the left the action of varying heat in the bottom of a boiler was exactly imitated. The ends or the middle of the boiler were lifted, as the case might be, followed by a corresponding action of the levers and balance weights. The simple manner in which this motion was permitted, without affecting the steam and feed pipe connections, was very remarkable. The author now prefers balance weights to volute springs, for several reasons, not the least of which is, that the former constitute of themselves a perfect pyrometer, indicating at a glance the relative expansion or contraction of the bottom of the boiler, and consequently the inten ity of the heat below. The exploded boiler had been for some months replaced by another upon the previous type, but the bottom plates whereof were of Low Moor iron. The whole range of 15 were illustrated by a large diagram showing also the exact condition, as regards equality of support afforded by the several suspension rods, in which the author found them in a recent visit. Mr. Hawman, manager to Messrs. Lloyd & Co., had assisted and accompanied him in his observation. The boilers are in charge of an experienced foreman, Mr. Wandlass, who, in the author's opinion, bestows unusual care and watchfulness upon the management of them. With regard to the material and workmanship made use of in the construction of the boilers, the author said he was aware he was on tender ground, for his own firm had made the plates, and the well-known firm of Hopkins, Gilks & Co. constructed the boilers. Without either asserting or denying that the casualty was in any degree due to defects of material or construction, the writer did not hesitate to declare that Mr. Gjers, who at that time ably fulfilled the position of engineer to Messrs. Lloyd & Co., took at least ordinary care in getting well-made boilers, and good material, and that the firms referred to exercised at least ordinary vigilance in carrying out their contracts. Unfortunately, ordinary care on the part of employers did not always succeed in securing good work from employes, and, as they all knew, some uncertainty clings to iron products even when manufacturers have done their very best. He did not consider any useful purpose would be derived by discussing at length that part of the subject. Low Moor plates, at £20 to £30 per ton, were undoubtedly better than Cleveland-made ones at £9 5s. Drilling rivet holes was undoubtedly better than punching, and perhaps drifting them, but more costly. The point to which their attention could be directed with real utility, was, *not* whether boiler work could not be made to stand greater strains by employing more costly materials and increased care in manufacture, but whether boiler work, such as it is, and for the most part is likely to be, could not be relieved from some of the great strains to which it was commonly subjected, and, as he thought, unduly and unnecessarily. Referring to the diagram, the writer then called attention to the varying strains upon the several suspension rods. In some boilers the nuts were almost all tight; in one the weight was overhanging from the fourth bearer, throwing the bottom into a state of compression where the flame was hottest. In some the whole weight of the boiler and the water within was, for the moment, carried upon four bearers, in some three, in some two, and in one (No. 7) on the first bearer and on the nozzle at the other end, being a clear span of nearly 60 feet; one boiler (No. 8), which was off empty, was also resting alone on the first bearer and the nozzle, while in the centre it was arched up half an inch clear of its

support; another (No. 9) which was off but full of water, was resting on the first and last bearers, and 3-16ths in. clear of support at the middle. All were under steam except the last two. It was customary in the Cleveland district never to adjust the suspension nuts after a boiler had been once set to work; some, however, adjusted when the boiler was hot, and others when cool. The first method would keep the bottom always in a state of tension, which might become extreme when, in cooling, the boiler endeavored to lift up itself, and perhaps, the brickwork in contact with it; the second method would cause the bottom to be alternately in compression and in tension; it was difficult to decide which practice was the least, or, rather the most objectionable. Mr. Wandlass preferred the first method, but said is was no easy matter to carry it out, for the slightest variation in the intensity of the flame, made some nuts too tight and others too slack. In fact he found it impossible to keep them all bearing equally at all times. The evils described are all greatly aggravated if, when laid off, boilers are allowed to cool too rapidly. Messrs. Lloyd & Co., allow 48 hours before a man can enter. With age a boiler increases its tendency to rise in the middle in cooling, indicating a permanent and gradually increasing contraction of the bottom plates. The author then referred to various details of boiler construction, he condemned hemispherical ends and especially nozzles, while he advocated dished and flanged ends made from a single plate. He also recommended strongly the use of a semi-cylindrical internal tank, for the harmless accumulation and periodic removal of whatever mud might enter with the feed water. He then went into a calculation of the strains to which the plates at the bottom of a boiler as unfavorably supported must be subjected as in No. 7 the strain from steam pressure was only one ton per square inch. That from the weight of the water and the boiler itself, he calculated to be about 4 tons per square inch, in addition, while there were other strains which could not be estimated. By adopting yielding supports the 4-ton strain and some others could certainly be removed. Since the previous portion of his paper had been written, another of Messrs. Lloyd & Co.'s boilers (viz. No. 13), had failed by a seam rip across the bottom, and situated about 2 feet 6 inches forward of the bearer. It went with "a snap" while cooling down and when the water had partly run out. By reference to the diagram, it was evident that at the author's first visit, this boiler was resting mainly on the end bearers. On cooling it would have endeavored to lift its centre portion, and perhaps the brickwork still more, and to rip a seam proved the smaller task of the two. In conclusion the writer disclaimed having selected Messrs. Lloyd & Co.'s boilers as bad specimens. He considered them good ones, and that if they were unsafe, there were hundreds of others which were much more so. Seam rips had occurred at various works, to boilers by various makers, and constructed of various brands of iron. He knew cases himself where Mon-Moor, Dowling, and Low Moor plates had similarly failed. Before taking his seat he would like to say that his object was not to prove that his remedy was the only one possible, for Mr. E. B. Marten had also one of great merit, but he wished to call renewed attention to a serious evil, which he believed could be and ought to be removed forthwith.

PROGRESS OF THE IRON AND STEEL INDUSTRIES.

Abstract of the report of DAVID FORBES, F. R. S., etc., to the Iron and Steel Institute.

From Journal of the "Iron and Steel Institute."

AFRICA.—In consequence of the continuance of the civil war in Spain, and the interruption thereby caused in the mining operations and exportation of iron ores from the district of Bilbao, still more attention than hitherto is now directed to the exploration of the deposits of rich iron ore which are met with so abundantly on the Mediterranean coast of Africa, and large quantities of these ores are now exported not only to France as before, but also to this country, Belgium, Germany, and even to the United States. In the first ten months of 1873, France imported 232,805 tons of iron ore from Algeria.

From New York, it is announced that about 20,000 tons of iron ore have, during the course of the last summer, been im-

ported direct from Bona, in Algeria, one-half for the Bethlehem Works, and the remainder for the Trenton Steel Works. It cost about 48s. when delivered in New York, and was guaranteed to assay sixty per cent. metallic iron along with about six per cent. of manganese; this ore was intended to be used for the production of Bessemer pig iron.

The total production of iron ore in Algeria, in 1872, is given at 334,924 tons, and the total quantity exported to all countries during the interval from 1862 to 1870, at about 800,000 tons; from one mine alone, 55,000 tons of ore was exported to England in the first eleven months of 1872.

M. de Marigny, late director of the Geological College of Algeria, has recently reported upon some large deposits of iron ore which crop out on the right bank of a small river called the Oued-el-Keddache, and are situated at an elevation of about 830 feet above the sea level; about two miles from the port "Aux Poules," and on the line of the projected railway from Algiers to Bongie and Delhys, which passes through the concession of some 2,000 acres in area, held from the government direct upon the usual royalty on all ore extracted. The lode is seen to follow the right bank of the river for some sixty yards, where it is from 36 to 60 feet in width; judging from the numerous large detached blocks of ore strewed on the surface for a great distance it would appear probable that this deposit is a very large one. The ore was found to contain 65·9 per cent. metallic iron, and to be free from both sulphur and phosphorus.

A paragraph has been going the round of the newspapers to the effect that there have recently been discovered, close to the Hills of Moses, near the Red Sea, the remains of immense ironworks, supposed to be at least three thousand years old, and which must have given employment to thousands of workmen. Near the remains are still to be seen the ruins of a temple, and of barracks for the soldiers who have been employed in protecting or keeping the workmen in order.

Australia.—Valuable deposits of iron ore, with seams of coal and fire-clay, are reported as having been discovered in the Strzelecki Range, Gipp's Land, in the property of the Great Victorian Gold Mining Company. At Ballarat, eight veins of ironstone, which contain from 50 to 60 per cent. of metallic iron, and are said to be from 30 to 40 feet in thickness, have been met with on the western slope of the Moorabool river, in Victoria; deposits of fire-clay and lignite occur in the neighborhood, and the country is covered with timber, which could be used for making charcoal.

Austria.—The great event of the year in this country was naturally the international exhibition, of which, however, so many and so detailed descriptions have already been given in other periodicals, that it is not considered necessary in the present report to make more than a passing reference, and to remark that such exhibits in connection with the iron and steel industries, as were particularly noticed, will be described under the heads of the various countries from which they proceeded. Although, as regards iron and steel, the Austrian and Hungarian works were well represented, there did not appear to be anything specially interesting for its novelty among the exhibits. From the Suedbahn Eisengesellschaft's Works, at Graz, in Styria, excellent steel rails manufactured by both the Siemens-Martin and the Bessemer processes were exhibited, as well as iron rails puddled in the Danks' rotary furnace; among other exhibits were, iron and steel from Kamatow; iron castings from Archduke Albrecht's works, at Teschen; steel and castings from Janowitz, in Moravia; and irons from Siebenburgen and Hungary; good specimens of cast iron railway wheels were sent from Count Andrassy's Dornac Iron Works, in Upper Hungary, and also by Messrs. Ganz & Co., in Pesth; and from the Reichenauer Iron Company's mines and furnaces at Edlach and Reichenau, near the Semmering, on the Styrian frontier, fine cast iron shells were exhibited, one of which, nine inches in diameter, had perforated an eleven inch armor plate without other signs of injury than some three or four minute cracks at the commencement of the ogival part.

Specimens of iron dephosphorized by Jacobi's process, which some time back was described in these reports, were exhibited by the Kladno Iron Works.

Belgium.—Since the publication of our last report, the continental meeting of the Iron and Steel Institute has been held, in August, in Liége, with such pronounced success, that the event may literally be regarded as the inauguration of a new era in the history of the iron and steel industries of Europe. This meeting, besides

being an announcement to the world of the cosmopolitan character of the Iron and Steel Institute itself, as well as the first occasion upon which the representatives of the British manufacturers could come into personal contact with those of Belgium and many other parts of Europe, who had come to Liége for the meeting, has, by its brilliant success, also proved that the time has arrived when it is at last acknowledged that the interests of the individual manufacturer in all countries is most intimately connected with the scientific and practical development of the industries themselves as a whole, and that to shut himself up within the walls of his works, isolated from the rest of the world, is infinitely less to his advantage than to trust to his own merits and enter boldly into the list of friendly rivalry with his competitors. That this spirit animated the ironmasters and engineers of Belgium, when they invited the members of the Iron and Steel Institute to hold their annual meeting in Liége, with a view to a mutual interchange of ideas relating to these industries, was thoroughly demonstrated on the occasion of the August meeting, and the numerous excursions made to the surrounding metallurgical and mining establishments, which, in the most liberal manner, were thrown open to the inspection of the members. It was, indeed, a happy thought which suggested that Belgium should be the first country to welcome the Iron and Steel Institute to the continent of Europe, since this country, apart from the political and commercial relations which have long allied it to Great Britain, was in the fortunate position of a neutral ground during the disastrous war which so lately raged on the Continent. We must refer elsewhere for an account of the meeting itself, with its pleasant excursions, brilliant fêtes, and the lavish hospitality with which the city of Liége, the great establishments in its vicinity, and even His Majesty the King, at Brussels, entertained the members of the Institute, but we cannot refrain from alluding to the unmistakable cordiality of a reception which above all made the members of the Institute carry home with them to England the most pleasing souvenirs of their Belgian friends and hosts.

As an iron producing country, Belgium now ranks fourth in Europe, and fifth in the world; Great Britain taking the lead, followed at an immense distance by the United States of America, and then by Germany or France, the last country having probably lost its position since the annexation of Alsace and Lorraine to Germany; Belgium follows close on their heels, and, with the exception of the above-mentioned, still has a production of more than double that of any other country in the world. The extraordinary rapidity with which the Belgian Iron manufacture has developed itself of late years, is well seen in the case of the Charleroi basin, which, in 1842, produced 40,000 tons of pig iron; in 1852, 81,821 tons; in 1862, 199,790 tons, and in 1872, attained the large amount of 400,000 tons,—thus, in other words, increased 218 per cent. in the first decade, 499 per cent. in the second decade, and no less than 1,000 per cent. in its third decade. Nor did the manufacture of wrought iron remain in arrear of the cast iron production, as, while in 1842 it was only represented by 20,000 tons, it became, in 1852, 37,326 tons; in 1862, 112,290 tons, and in 1872, about 250,000 tons, which figures show an increase in production of 177 per cent. on the first decade, 534 per cent. on the second, and as much as 1,190 per cent. on the third decade.

The state of the Belgian iron trade during the last half-year, 1873, has been extremely unsatisfactory, notwithstanding that the production both of the blast furnaces and rolling mills has been greatly restricted; up to date there appears but little hope of improvement. The steel trade, however, has not suffered in nearly the same degree, and the production of steel is, on the whole, being increased; it is reported that the Société de Sclessin, have applied one of their blast furnaces to the production of Bessemer pig iron.

From the Bulletin de l'Union des Charbonnages, &c., de la Province de Liége, we learn that the Belgium iron trade, taking into consideration its increased proportions, has of late become more and more dependent upon Luxembourg and other countries for its supply of ores; the reason assigned for which is, that the mining laws of Belgium do not favor the development of its minerals.

Brazil.—Immense deposits of magnetic iron ore of the richest class are reported to have been discovered in the Province of St. Paul, at a distance of only some 8,250 metres from the river Jacripiranga, at a point where flat-bottomed steamers can ascend to. Limestone of a bituminous

character, supposed to be indicative of coal, is found in the vicinity, and the whole of the country is covered with virgin forests. An imperial decree concedes these mines to Don Joachim Ignacio Silveira da Motta, and grants permission to found a colony and occupy the land at an extremely low price.

Burmah.—From the report of Captain G. A. Strover, political agent, Mandalay, on the mineral resources of Upper Burmah, published by order of the Government of India, we learn that iron ores occur in abundance in the Shan States, especially in the district of Pagan, south of Mandalay, where it is smelted in a rude manner and on a small scale at Pohpah Toung. Westwards of Sagaing, for miles up the Irrawaddy river, rich hematite iron ore is found in great quantity, and the Burmese government are now awaiting the necessary machinery and materials from England, for erecting works at Sagaing, for smelting the hematite, it being expected that the surface ore will fully supply these works for years in advance, without mining being resorted to. Limestone is found in abundance, and coal is known to occur in several parts of the Shan States, especially at Meimbaloung, where the deposit has been inspected by a mining engineer and reported to be equal to the best English coal in quality, and to pertain to the true carboniferous formation.

It is proposed to erect new iron and steel works on the right bank of the river Irrawaddy, about twelve miles below Mandalay; these will contain two blast furnaces, forge and rolling mill, and steel works for making crucible cast steel.

Canada.—It is announced that a company has recently been formed for the purchase of the Haycock iron mines, near Toronto. It is in contemplation to erect blast furnaces and Bessemer converters for making steel, Mr. Holley's estimate of making Bessemer steel being £8 per ton.

A proposition has just been made to the inhabitants of Ottawa, to erect steel works there, which will employ 400 workmen, and require a capital of £100,000; the town of Ottawa being asked to find the ground with buildings, worth together about £30,000.

The recent report of Mr. Richardson, the Dominion Geological Surveyor in Vancouver's Island, shows that there is an apparently inexhaustible supply of iron ore in that district, especially on Texada Island, where enormous deposits of the richest and purest iron ores are stated to occur. As excellent limestone occurs in abundance in their immediate vicinity, and extensive beds of bituminous coal are close at hand, there would appear to be every element at hand required for the successful establishment of the iron manufacture in this colony.

China.—Some information on the state of the iron manufacture in this country may be gleaned from the inspection of a series of specimens of the ores and manufactured products contained in the Chinese department of the Vienna Exhibition, exhibited by M. Prosper Giquel, the manager of the Imperial arsenal at Fu-tschew, in the province of Fu-Kian, in the south of China, who at the same time has afforded some information as to the mode of manufacture carried on in that province. The ore itself is magnetic oxide of iron in small grains, which are disseminated through the sand arising from the disintegration of the granitic rocks, which occur on the eastern slope of the Tajueling range of mountains, and are carried down by river action to the lower parts of the country, where they are washed in troughs by the natives until the lighter particles are carried away and there remains dark-colored sand, consisting chiefly of magnetic oxide of iron, in quantity amounting to about from 1½ to 2 per cent. of the weight of the original sand. This sand is then smelted with charcoal in small tapering blast furnaces, made of refractory clay and bound together by iron rings, the blast being produced by wooden bellows worked by men, and the furnace fed with equal weights of iron ore and charcoal. The product obtained is a mass of crude iron, containing fragments of slag and charcoal, 500 lbs. of the iron sand only yielding about 150 lbs. of reduced iron, which, after being again treated in the same furnace with about half its weight of charcoal, becomes a bloom of more or less steely iron, weighing about 83 pounds. While still hot this bloom is hammered down into bars of about one inch square, which, when cut across into lengths of six inches each, are ready for the market, and are sold to the arsenal at Fu-tschew, at a price of about £11 per metrical ton (2,205 lbs. English). As the bloom of 83 lbs. only corresponds to about 17 per cent. of the weight of the iron sand em-

ployed in the first instance, it is evident that there must be an enormous loss of iron in this process, since the iron sand itself cannot be estimated as containing less than between 50 and 60 per cent. of metallic iron. It appears, however, that the Chinese Government, following the example of that of Burmah, are about introducing important reforms in the iron metallurgy of the Celestial Empire, as they have had a mandarin engaged this last summer in studying the iron manufacture in the United States of America.

France.—If we are to judge from the speech made in November, at Lyons, by M. Desseillgny, the Minister of Commerce, after his recent tour among the French ironworks of the southern and central districts, there seems to prevail a very high opinion as to their future capabilities, the Minister declaring that they were then in a position to compete successfully with England, and that this favorable state of things ought to encourage them in their efforts to conquer a predominating position in all the markets of the world. He considered the main element to be improved means of communication, especially by inland navigation, and, referring to the Loire iron mining district, which last year had turned out four millions of tons, considered that this might and would be doubled.

The official returns for the first ten months of this year show that 637,956 tons of iron ore was imported during this period, of which 99,590 tons were from the Belgian frontier, 163,519 tons from Spain, 232,805 tons from Algeria, and 111,686 tons from Italy; the whole quantity shows an increase of some 66,000 tons, or about eleven and a-half per cent. over the corresponding period in 1872, which increase is entirely due to the larger importations of ores intended for the manufacture of steel. The imports of metals amount to 108,938 tons of pig iron, 41,109 tons wrought iron, and 5,500 tons of steel; the total imports of pig iron show a diminution of 1,213 tons, or about one per cent., as compared with the same period in 1872, while the quantity of wrought iron was also less by 1,808 tons, or nearly four and a-half per cent. The total exports amounted to 208,693 tons, of which quantity 126,431 tons are the direct ordinary exports, the remaining 82,262 tons being sent out under the special decree which admits pig iron, &c., duty free for manufacture and subsequent re-exportation. The exports, under the above-mentioned decree, show an increase on those of the corresponding period of last year of more than 9,000 tons, or about eleven per cent., while the ordinary exports, on the contrary, are 6,970 tons, or 5-3 per cent. less. From the above figures it would appear that the exportation of French iron has remained about the same as during the previous year, but that less foreign iron has been imported in the same period of the current year.

The steel manufacture in France has gone on steadily progressing, and but little affected by the slackness in the iron trade, as is shown by the quantity of ores suited for steel making now imported, and which, in the first six months of this year, was no less than 40 per cent. more than in the corresponding period of 1872. A company with a capital of two millions of francs was formed, in September, in Paris, for manufacturing steel by Gallet's process.

The Western of France Railway Company, which, up to the close of 1872, had laid down steel rails for more than 146 miles, are extending their employment still further.

Germany.—The technical journals of this country, although usually so rich in data for forming a sketch of the progress made in the iron and steel manufacture of the Empire, have during the past months been quite the reverse. In the Berg-und Huetten-Mænnische Zeitung, for the 12th September, will be found a paper on the iron mines of Upper Silesia, and their system of working, by B. Turley, which, however, does not possess any features of interest for the English ironmaster.

From a description of the celebrated steel works of M. Krupp, at Essen, we extract the following particulars:—These works, which at the commencement of this year covered a continuous area of about 1,000 acres, of which 200 acres are under roofing, along with the mines, give employment to about 17,000 workmen, exclusive of 739 foremen and employes, who are in part lodged in 2,948 houses, besides 266 dwellings for the employes, and two hospitals, one with 100, and the other, for infectious diseases, with 120 beds. A body of 166 watchmen, and a permanent fire-brigade of 70 men, who also perform police duty, are employed. The commissariat department has under it—one hotel, three beer-houses, one seltzer water manufactory, a flour mill and a bakery, containing two

steam engines, besides extensive general supply stores, where all connected with the works can purchase, for cash, provisions, clothing, dry goods, &c., at cost prices. There are also a chemical laboratory, photographic, lithographic, and bookbinding establishments, as well as a printing-office, which employs two steam and four hand-presses. A sick, burial, and pension fund has been instituted, to which M. Krupp contributes half as much as the workmen; the annual receipts of this fund amounted in 1872 to £16,000—another fund provides medical treatment to its members on payment of three shillings per head annually.

The number of mines belonging to the works is 414, covering an area of some 50,000 acres, besides which, mines in the North of Spain have been recently acquired, from which an annual supply of some 300,000 tons of ore, suitable for steel making, are expected, as soon as the railway, nearly eight miles in length, now in course of construction (as well as several steamers) is completed.

One hundred and forty coke ovens are in work, and 120 additional in course of construction, these supply eleven blast furnaces with fuel, which turn out nearly 10,000 tons of pig iron per month.

In 1872, the works consumed 500,000 tons of coal, 125,000 tons of coke, and 113 million cubic feet of water, while the gas works on the premises supplied 155 million cubic feet of gas through 16,500 burners.

To facilitate the traffic in the works, there are about 24 miles of usual gauge railway track, with 180 sidings and 39 turntables, which are worked by 12 tank locomotives with 16 inch cylinders and 530 wagons. Ten miles of narrow 2 feet 6 inches gauge track, with 147 sidings and 65 turn-tables, are also worked by three locomotives with 6 inch cylinders and 270 cars; and in addition 191 horses are employed, Communication between the various parts of the works is maintained by thirty telegraph stations.

The works themselves contain 250 smelting furnaces of various descriptions, 390 annealing do., 161 re-heating do., 115 welding and puddling furnaces, 14 cupolas, and 160 furnaces of other kinds, besides 275 coke ovens, 264 smith's forges, and 240 steam boilers.

In the workshops are to be seen 286 steam engines, 71 steam hammers, 362 lathes, 82 shaping machines, 195 boring do., 107 planing do., 42 punching and grooving do., 32 pressing do., 63 grinding do., 31 glazing and polishing do., and 142 other miscellaneous machines.

The quantity of cast steel made in these works in 1872 exceeded 125,000 tons, in the shape of axles, tires, railway wheels, crossings, rails and springs, shafts, artillery shot and shell, boiler plates, &c., the qualities of which are too well known to require any comment, and many of which were well represented at the Vienna Exhibition, particularly in the case of artillery.

Drawings and description of a pair of powerful blowing engines, made by Messrs. Galloway for these works, will be found in *The Engineer* for November 21, 1873. These steel works were lately insured against fire in some twelve German offices for the sum of 6,513,306 Prussian thalers, or not much less than one million sterling.

It is reported that M. Krupp has made known that any workman or employe at the steel works who may take part in the discussion of the religious questions now causing so much trouble in Germany will be immediately dismissed.

Greece.—It is a considerable time since we have been able to communicate any information as to the iron mines or metallurgy of this country; it appears, however, from the recent number of the *Levant Herald*, that the Hellenic Mining Company has contracted for the exportation to England of large quantities of rich iron ore from its mines in the Island of Seriphos; it is also stated that the large works erected by Tubine, near Newcastle, under the name of the Royal Creek Iron works, for smelting these ores, have commenced operations.

India.—As giving a very good summary of what is known about the modern attempts at iron making in British India, we have been induced to reproduce the following remarks from the *Times* of September 8th, 1873:—"Iron producing minerals are widely scattered over India. There are magnetic and special iron ores and red hematite in beds and veins; there are clay iron ores from the coal-bearing strata; and there are surface deposits derived from the waste of metamorphic and sedimentary strata, and from laterite. The latter formation contains from 20 to

30 per cent. of iron. Some of the most remarkable deposits of magnetic iron ores are in the Salem district of the Madras Presidency. The ores occur in immense beds, 50 to 100 feet thick, and the outcrop may be traced for miles. On one hill, six miles from Salem, there are five bands of magnetic iron from 20ft. to 50ft. thick. At Lohara, in the Chanda district of the Central Provinces, there is a hill two miles long, and a half a mile broad, the surface of which is covered wifh masses of almost pure iron ore. In Bandalkhand and in the Narbada valley there are large quantities of hematite ores ; the supply in many cases is practically inexhaustible. The clay iron ores in Raniganj and other Damuda coal fields yield 39 per cent. of iron. The Kamaun iron ores form an argillaceous band, containing large quantities of red hematite, the ore bed being 10ft. to 20ft. thick, and extending for a long distance. The surface deposits supply the greater proportion of ores used by native smelters, but much labor is necessary in the collection. Iron has been manufactured in India from time immemorial, and iron weapons are found in the ancient cromlechs and kistvaens, but there never were any large works. The production of iron is the work of poor people of very low caste, scattered over the country. They have small clay furnaces, with charcoal for fuel, and the blast caused by foot or hand bellows. The smelting goes on for eight or ten hours, at the end of which time from 10lb. to 20lb. weight of iron is found at the bottom of the furnace ; this is purified by reheating and hammering, and the resulting is generally of excellent quality; but the native manufacture is rapidly decreasing, owing to the difficulty of obtaining charcoal. All attempts by the English to manufacture iron in India have hitherto utterly failed. In 1825 Mr. Health, of the Madras Civil Service, obtained a Government advance, and formed a company to establish iron works at Porto Nova, near Cuddalor ; at Polamputi, near Salem ; and at Bepur, where the iron was obtained from laterite ; but the result was nothing but failure, attributed partly to the distance of the works from the source of supply and to the scarcity of charcoal. In 1857, Mr. Sowerby, and engineer, reported on the iron ores in Kamaun, but repeated attempts to work them ended in financial failure ; and a similar attempt by a Calcutta merchant, who started works near Suri, in Birbhum, was also abandoned. The enterprise of the Government in the Narbara Valley promised well, and might have been most successful. Works were erected at Burwai, on the Narbada, under the auspices of Colonel Keatinge ; Mr. Mitander, a very able Swedish metallurgist, was induced to take charge of the works, and after many experiments all difficulties were overcome, and the works were ready for the production of iron Suddenly in 1864, the Government, after spending £75,000 on these preliminary expenses, dismissed Mr. Mitander, closed the works, and offered them for sale, without success. They have now, with the ground on which they stand, been made over to Holkar. Iron ore and limestone abound in the neighborhood ; large forests, furnishing supplies of charcoal, extending for many miles to the east and northeast ; and Mr. Mitander was an excellent manager. No record has even been preserved of his experiments and plans for burning and storing charcoal and for other processes which would have been useful at a future time. This year's *Statement relating to India*, referring to these facts, notices that the Government are now once more nxious to foster the iron manufacturing industry of India. Last year Mr. Bauerman was sent out to report on the subject. The increased price of iron is most favorable to the prospect of the manufacture proving profitable in India. The use of Indian coal for smelting iron has never yet been tried.

Italy.—From a report on the conditions of the mining industry, in the Island of Sardinia, by M. Sella, the Minister of finance, a translation of which is to be foundin the *Revue Universelle des Mines*, vol. 33, we learn that veins of magnetic oxide of iron are abundant in several of the geological formations, but that their positions render cheap transport of the ore to a shipping port out of the question except in the single instance of the mines of Saint Leon, Capoterra, on the Gulf of Cagliari, which were in 1861 purchased by the French company, Petin-Gaudet et Cie, for the sum of 29,000 frants, along with an annual payment of 1,360 francs, and in 1863 obtained the definite concession over

360 hectares, or nearly 900 acres. An analysis of the ore was given in our second report for 1872.

The lode or lodes, for there are two, known respectively under the names of Gaudin and Petit, have the direction of the magnetic meridian, and dip into the Silurian Slates to the westward; their outcrop is situated at a height of 400 metres above the level of the sea. The ore had consequently to be brought down by three different inclined planes following one another, and then by a railway to the shipping place in the bay; by these means some 240 to 300 tons per day could be shipped, but the arrangements were so expensive as to cost the company about one-and-a-half million francs before completion, and when the ore had to be mined out by regular workings underground, it was found that while the extraction of ore at the surface did not cost above two shillings per ton, it soon increased to about four times this amount, and the expense of placing the ore on board ship in the bay of Cagliari, without including the expense of management and general charges, was found to be, according to data obtained from M. Gouin, the manager of the mine as follows:—

Mining and Extraction	9·24	francs per ton.
Transport by inclined planes	1·47	" "
Do. by railway to the sea	3·75	" "
Putting on board	1·90	" "
Total . . .	16·36	francs.

Which, in 1869, when the price of the iron ore on board ship at Cagliari was not more than from 9 to 11 francs per ton, according to its quality, was not found to pay, and consequently the workings, which employed some 300 men were abandoned, at least for the time. It is reported that they have since been resumed, although M. Sella does not consider that they can possibly compete as to price with the iron ores from either Elba or Algeria.

New Zealand.—From this colony we learn that a company has at last been formed by Mr. Walduck, in England for the purpose of smelting the Taranaki iron sand which has so long been before the British public. On the authority of the *Manchester Guardian*, of the 4th October, we give the following information:—"A number of British ironmasters have just acquired nearly 20 square miles of property in the Wharekawa district, in the province of Auckland, New Zealand. The property embraces 8,700 acres of coal and iron-stone. The chief seam of coal is found in some parts within a few yards of the surface as thick as 20 feet, and it is computed to be capable of yielding an average thickness of 10 feet throughout the whole 8,700 acres. This represents no less than 126,000,000 tons of good coal.

The ironstone is of the brown hematite class, and contains as high a percentage as 62 of fine iron, and is believed to yield an average of 50 per cent. Four specimens reported upon on Thursday, after analysis by a metallurgical chemist in the Midlands, showed 60, 59, 50½, and 36 per cent. respectively. Calcined, it will be worth in this country—as prices are just at present—30s. per ton. Made into iron upon the estate, the coal and iron-stone, estimated each at 8s. per ton, and the limestone, also found on the estate, at 7s., would enable a ton of hot blast pigs to be produced at £2 13s. per ton, and the quality would be equal to British iron which is now selling at £7. Made into cold blast iron, the cost would be about £2 17s. 6d., and the quality would be equal to the British iron which now realizes £8 per ton.

Russia.—The most recent information with respect to the iron manufacture of this country which we have come across, is contained in the Tableaux Statistiques de l' Industrie des Mines de la Russie, en 1871, published in connection with the Vienna Exhibition of this year, by M. Skaljkowsky; from there it appears that in 1871 the number of iron mines worked was 1,174, which turned out a total of 820,000 tons of ore, while in the same year the productions of the various smelting works amounted to 354,000 tons of pig iron, 30,000 tons castings, 241,500 tons wrought iron, and 7,000 tons of steel.

In the Vienna Exhibition, the iron manufactures of Russia are fairly represented. From the north, on the Gulf of Bothnia, samples of the so-called lake ores, a concretionary hydrated oxide of iron, often with considerable oxide of manganese, dredged up from the fresh water lakes, and of iron made from it, are exhibited from Tushby, Uliaborg, and Gamlekarlby; the district between Lake Ladoga and the Gulf of Finland shows white and mottled pig iron with plates, bar and angle iron of good quality, from the ironworks of Warschavsky & Co., at Raivolo, near Viborg, while a collection of the products of his ironworks is shown by Nicolas Poutiloff, of St. Petersburg,

who employs some 4,000 men in the works, or, including those in the mines, carters, charcoal burners, &c., about 18,000 in all. The cannon foundry of Oboukhoff sends a few good specimens of steel guns and mortars, while samples of merchant bar and plate come from the Kamsk forges, on the Viatka river. The great works of Demidoff, at Nijni-Tagil, exhibit pure magnetic iron ores, clay ironstone, and pig iron of excellent quality, while the Rastorgouieff Trustees, from Ekatarinburg, have wrought iron, rough and polished plates and art castings. The Stenbock-Fermor Works, which have seven blast furnaces, supplied with magnetic iron ore from the famous mines of Mount Blagadd, send a model of the works and also bar and sheet iron and samples of the pine charcoal used in its manufacture.

The Imperial Cannon foundry, at Perm, shows a model of one of the largest anvil blocks ever made, as it weighs 622 tons, and is intended for a 50-ton double action steam hammer; some good specimens of steel and steel cannons, and shell, are also to be seen in the arms department, among which was observed an eleven-inch shell, which, after having penetrated an eleven-inch armor plate, has sustained no other injury than having a small piece of the point broken off.

A collection of steel articles, as cutlery, &c., exhibited from Nijni-Novgorod, the Sheffield of Russia, do not come up to the English standard of finish, although probably the material is of excellent quality.

A Russian company has been formed for carrying on the very extensive works of M. Poutiloff, which consist of Bessemer converters, with rail rolling mills near St. Petersburg, puddling furnaces and rolling mill on the Nicolai Railway, and three iron-works in Finland, containing blast furnace, rolling mills, &c. The capital of the company is fixed at five million silver rubles, about £800,000 in shares, along with three million silver rubles, about £475,000, in 6 per cent. debentures.

In England, a limited company, entitled "Tiflis Iron Mines and Works," with a capital of £155,000, in shares of £100 each, was registered in September last, to acquire and work the Bolais Iron Mines and Iron Works, situated about 35 miles from Tiflis, in Asiatic Russia.

Spain.—The mineral and metallic statistics of this country are not only extremely behind-hand, but also when they are published are but little to be depended upon for accuracy; the official returns for the year 1870, which are of a very meagre character, have only been recently published by the Government, and will be found in the numbers of *La Mineria* for August 7th and 15th, 1873. From these tables it appears that while the number of concessions of iron mines in force on the 1st of January, 1870, was 582, it had increased to 615 on the 31st December of the same year. During the year 1870, 267 iron mines had been kept in operation by a force of 2,479 men, 162 women, and 152 boys, with two steam engines of a collective force of twelve horse-power, and a total yield of 4,365,861 metrical quintals of iron ore, which, reckoning the metrical quintal at 100 kilogs., will amount to 436,586 metrical tons.

The number of ironworks in operation in 1870 is reported as 75, with a production of 54,007 tons pig iron, and 36,162 tons wrought iron, and employing 3, 570 men, 151 women, and 452 boys, along with 154 water-wheels, representing 1,549 horse-power, and 120 steam engines of 3,796 horse-power.

The above figures show that the production of the year 1870 has exceeded that returned for the preceding year by 125,240 tons of iron ore, 19,521 tons pig iron, and 536 tons wrought iron.

Sweden.—In the fourth number of Jern-Kontorets Annaler, for 1873, will be found the particulars of experiments made by Mr. A. Grill, at the Huseby Iron Works, in smelting with a mixture of Swedish coal, uncoked, with charcoal in the blast furnace. The Swedish coal belongs to the cretaceous formation, is, properly speaking, a lignite, and does not coke when heated. The results of the trial smeltings showed, although a very troublesome stiff slag was produced, that the iron was of good quality, and indicated that when a good slag-making flux is employed, the coal could be used in a small proportion with advantage.

The two new charcoal blast furnaces erected by the Central Swedish Iron and Steel Company, Limited, at Bjorneborg, were put in blast in October, on Bessemer pig iron, and are in most satisfactory working; it is expected that the Bessemer works attached to them will be ready early in 1874, when the steel will be run into the converters direct from the blast furnaces.

The Bongbro new Bessemer works' blastt furnaces, and rolling mills, are being rapidly constructed, and will, it is expected, be very soon in partial operation.

At the Startnaes Works, about 47 tons of Bessemer steel ingots are made per week direct from the charcoal blast furnace, which is a small one; this quanity of steel represents between 88 and 89 per cent. of the total iron produced by the blast furnace, and this very satisfactory result is attributed chiefly to the ample power of the two double action blowing cylinders, which are worked by two turbines, each of 175 horse-power; at the commencement and end of the blow a pressure of from 250 to 300 lines of mercury is employed (exceptionally even as much as from 320 to 350 lines), but during the rest of the blow from 120 to 180 lines is found sufficient. By the employment of so high a pressure and quantity of blast, the duration of the operation is lessened and the temperature raised. The converters are lined with quartz, which stands some 60 or 70 blows.

An elaborate series of experiments made on the steel from the Fagersta Works, which fully bear out the good character of their products, has been published in quarto form, with numerous plates, by Mr. David Kirkaldy, entitled "Results of an experimental inquiry into the mechanical properties of Steel of different degrees of hardness, and under various conditions, manufactured by Christian Aspelin, Esq., Westanfors and Fagersta Works, Sweden. By David Kirkaldy. London, 1873."

In the Vienna Exhibition, a large cast iron breech-loading cannon of 24 centimetres calibre, with steel rings shrunk on it, is shown by the Finspong Iron Works, which have so long been known for their excellent cast iron artillery; from this gun 330 rounds had been fired, using 24 to 26 kilogs. of gunpowder, and an iron shot weighing 144 kilogs. Various other guns of smaller dimensions were also shown, and some surprise was expressed at the extremely low prices at which they could be delivered.

United States.—From the statistical report of the Secretary of the American Iron and Steel Association we learn that the production of pig iron in the United States in the year 1872 was 2,830,070 net tons, or 2,526,848 gross tons. This quantity was produced in twenty-one States. The ascertained production during the first six months of 1873 was 1,393,075 net tons, and he estimated production for the whole of the year 1873 is 2,695,434 net tons, or 2,406,637 gross tons. The number of States which made pig iron this year was twenty-two—Maine having re-entered the list after a long rest. The excess of production in 1872 over the estimated production of 1873 is 134,636 net tons. If the financial crisis had not occurred, the production of 1873 would have exceeded 3,000,000 net tons. The estimated annual capacity of all the furnaces in the United States is 4,371,277 net tons.

The total number of furnaces in the United States, exclusive of abandoned and projected furnaces, is 636. The total number of new furnaces finished and put in blast in 1872 was forty-one; finished and put in blast in 1873, forty-two; total number of new furnaces put in blast in the last two years, eighty-three. Many of these are among the largest in the country. By the erection of these eighty-three furnaces, the furnace capacity of the country has been increased fully one-fourth; and what is considered as a pretty close estimate of the entire production of rolled and forged iron, in the United States, for the last two years, is given, in net tons of 2,000 lbs. each, as follows:—

	1872	1873
Merchant bar and rod	500,000	400,000
Sheet and plate	200,000	250,000
Hoop	30,000	30,000
Nails and spikes	175,000	200,000
Axles, etc.	95,000	100,000
Total net tons	1,000,000	980,000
Add iron and steel rails	941,992	850,000
Total rolled iron, net tons	1,941,992	1,830,000

The production of cast steel in the United States is estimated as likely to be about 28,000 tons, or some 4,000 tons less than the quantity returned for 1872; on the other hand it is expected that the production of Bessemer steel will amount to 140,000 tons against 110, 500 tons last year; about 85 per cent. of the Bessemer steel made in the United States is rolled into rails. The total quantity of pig iron converted into Bessemer steel during the first nine months of this year was 127,384 tons, which was more than the quantity converted in the entire year 1872, that being 125,361 tons. The production of steel by the Siemens-Martin process is only a few thousand tons annually, and is confined to seven establishments; one new establishment was inaugurated this year, but it does not appear that steel can be manufactured as cheaply in the States by this system as by the Bessemer process.

The Bessemer steel works at present in operation can turn out annually 170,000 tons of rails, and are situated at Troy, in New York; Johnstown, Harrisburg and Bethlehem, Pennsylvania; Newburg, Ohio; and at Chicago (2) and Joliet, Illinois. When the new plant now being put up at the Pennsylvania Steel Works, at Harrisburg, which will double their present capacity, and the Edgar Thomson Steel Works, near Pittsburgh, are completed, the total capacity of the Bessemer works in the United States may, in 1874, be estimated at about 222,000 tons of steel rails per annum.

For the manufacture of pig iron for conversion into steel by the Bessemer process, it has been found advantageous to import rich iron ores from Algeria by the firms of Cooper, Hewitt and Co. and the Bethlehem Iron Company; for the same purpose a trial cargo of iron ore from Bilbao, containing fifty-three per cent. metallic iron, has also been received by the Pennsylvania Steel Company, and is reported as of excellent quality.

The following figures show a summary, in net tons, of the ascertained and estimated production of iron and steel in the United States in 1872 and 1873:—

	1872.	1873.
Iron and steel rails	941,992	850,000
Other rolled and hammered iron	1,000,000	980,000
Forges and bloomeries	58,000	50,000
Cast steel	32,000	28,000
Bessemer steel	110,500	140,000
Siemens-Martin steel	3,000	3,500
Pig iron	2,830,070	2,695,434

GREAT BRITAIN.—Mr. Robert Hunt, F. G. S., the Keeper of the Mining Records, has lately issued the volume of the Mineral Statistics for 1872. From this it appears that, as far as regards the iron trade, 16,638,599 tons 2 cwts. of iron ore (of which returns were received) were raised in 1872, as compared with 16,859,063 tons 14 cwts. in 1871, and 14,370,654 tons 18 cwts. in 1870.

Pig Iron Manufacture.

The total quantity of iron ore smelted in Great Britain, amounted in 1870 to 14,578,964 tons; in 1871, to 16,859,063 tons; and in 1872, to 16,539,889 tons.

Pig Iron Produced.

	1870. tons.	1871. tons.	1872. tons.
In England	3,735,627	4,379,370	4,594,614
In Wales	1,021,888	1,087,809	1,057,315
In Scotland	1,206,000	1,160,000	1,090,000
	5,963,515	6,627,179	6,741,929

In 1872, the quantity of coal used in the production of this pig iron was:—In England, 11,388,342 tons; in Wales, 2,607,887 tons; and in Scotland, 3,215,500 tons; or a total of 17,211,729 tons. Coke had been computed as coal.

The average number of furnaces in blast in England during 1872 was 449¾; in Wales, 122¼; and in Scotland, 130; total, 702.

The following is a summary of puddling furnaces in operation in the years 1870, 1871 and 1872:—

COUNTIES.	1870. No. of Puddling Furnaces.	1871. No. of Puddling Furnaces.	1872. No. of Puddling Furnaces
Northumberland	54	44	54
Cumberland	95	89	86
Durham	951	1,053	1,135
Yorkshire (Cleveland district)	542	529	492
Yorkshire (Leeds and Bradford district)	247	236	282
Yorkshire (Sheffield and Rotherham district)	353	342	383
Derbyshire	94	91	108
Somersetshire	19	19	19
South Staffordshire	2,037	1,934	2,155
North do.	429	406	446
Shropshire	218	206	184
Lancashire	154	192	178
NORTH WALES	54	54	66
SOUTH WALES—			
Glamorganshire	613	568	594
Brecknockshire	86	62	20
Monmouthshire	553	535	637
SCOTLAND	339	339	486
Total	6,841	6,699	7,311

The number of rolling mills to which the furnaces in 1872 worked was 1,015.

Coal Production of the United Kingdom.

The statistics relating to the production of coal, during the year 1872, will be of interest. Mr. Hunt furnishes the figures which were returned to the inspectors in the various districts at the close of that year. In 1870, he shows that 110,431,192 tons were raised; in 1871, 117,352,028 tons; and, in 1872, 123,497,316 tons.

ON THE STEAM BOILER EXPLOSION AT THE KEYSTONE MILLS.

By W. BARNET LE VAN.

Written for Van Nostrand's Magazine.

On Friday, May 8th, 1874, shortly after three o'clock, a boiler exploded at the above mill, which is occupied by a number of small manufactories. The power is furnished from six plain cylindrical boilers thirty-six inches in diameter and thirty feet long, located on the outside of the mill. The boilers are set in the usual way, two

in each set, three sets; three sets in all, each set fitted with all the appliances required by law. The two sets adjoining the mill having proved sufficient to drive the mill until within a few days prior to the explosion. Owing to a lot of bad coal it was found necessary to fire up the third set which had been standing idle for some time back; one of the boilers was repaired in January last so as to be in readiness in case it was needed. It having been examined by the inspector of a prominent Boiler Insurance Company, under whose charge it was; and the repairs being ordered to be done prior to its being put into service again.

On the afternoon of the explosion the engineer noticed a leak in the repaired boiler, it being the outside one of the third set; he immediately banked his fire, shut off the connections from the other two sets, and was in the act of attaching a pipe to blow them off when the explosion took place.

The boiler parted at the junction of the second and third rim. The front end, consisting of the front head and two rims, was hurled a distance of 150 feet eastward, passing through a shed and landing near the gas-works wall. The back head, with about twenty-five feet of the shell, was shot westward through a coal pile and across a cart-way into another coal pile which was heaped against the wall of the American Soap Company's works, 100 feet distant, the resistance of the coal arresting its flight.

The engineer, Hugh Sweeney, was badly scalded, besides receiving other injuries, and a boy named Thomas Ivan Devor, aged thirteen years, who was employed in the mill, was thrown a distance of sixty feet—both died the following day.

In the coal-yard where the last named piece of boiler landed, and at the time of the explosion, a carter was trying to back a pair of mules attached to a coal-wagon, to a point on a line of the flight of a portion of the boiler, but they were displaying their well-known trait by refusing to back, which fortunately saved them as well as the carter, from instant death.

From a careful examination of the exploded boiler, there is no doubt that it exploded because it was *broken*—"worn out"—it having been in use over twenty years. The average duration of boiler-life is *ten years*.

At the point of fracture, which is in thickness No. 5 or .22 inch, it having been originally No. 4 or .238 inches, it was cut in twain part way through the line of rivets and part way on the line of caulking, no doubt due to a fracture of long standing, from the fact that in two places there was no juncture of the metal, and the circle of the two parts was not distorted in the least by the rupture. This last circumstance satisfied me that a fracture had been in existence for a long time, and that the placing of the new piece on the boiler at this point (the rent passing through the line of rivets which held the new piece to the old rim) and of the same thickness (.238) as it was originally made, was the true cause of the disaster, the old iron having, by long continued use, passed its *elastic limit*, and perhaps beyond it, and the new piece being fresh in its elasticity tended to force apart the fracture and start the rent then in existence.

I would ask the Institute to use its influence with the City Council to have the present Inspection law so changed that there be a limit in the time of the use of boilers.

During the last twelve months there have been thirteen lives lost, beside a large number maimed for life by boilers over twenty years old.

My experience, based on the general usage of boilers of all kinds and conditions, satisfies me that ten years is the average duration of a steam boiler.

EUROPEAN RAILWAYS—AS THEY APPEAR TO AN AMERICAN ENGINEER.

BY W. HOWARD WHITE, C. E.

Transactions of the American Society of Civil Engineers.

A railway built upon the Amsrican idea of first getting the line built on a cheap system, and then bringing it up to first-class rank as the receipts permit, is a thing almost nnknown in Europe. In but one case, the writer noticed a road being built upon the economical plan, with wooden bridges.

One thing that strikes an American curiously is the immense amount of trouble

taken by engineers in laying out work for contractors. The immense number of all sorts of signals, grade posts and profiles, the latter not only for banks and cuts, but even for borrow-pits, would render nearly double the number of engineers necessary with which an American road is built.

In making banks, it is the practice to remove the surface of the ground, in case it is either of bad material, or where it furnishes sod for covering slopes, which are almost always either sodded or carefully planted with grass seed, producing undoubtedly a great saving in the after expense of cleaning ditches in cuts. Upon one road in the Tyrol, a curiously favorable combination of circumstances was seen in a low bank across a meadow, formed from side borrows. The sod from the base of the bank was just sufficient to sod the slopes, and at the bottom of the side borrows was found a nice layer of clean gravel for ballast.

Tunneling has been carried to a point in parts of Germany—notably in the Brenner Pass in Tyrol, and on a new road in the Black Forest—the equal of which would be hard, if not impossible, to find in other countries. In one place on the latter line, the engineer having run his grade into the bottom of the valley he was climbing, boldly turned somewhat more than a quarter circle directly into the hill—instead of crossing the valley—and came out again on the same side of the valley, above his previous line. At another place he made a curve of somewhat 90° underground, and then reversed for 30° before coming out again into daylight. The plan of this Black Forest line is a curiosity of itself. It presents two complete S's, in the necessity the engineer was under to get the distance for a certain grade, and there are 25 tunnels in a distance of less than 17 miles, ranging from mere bridge arches in point of length, up to the summit tunnel, which is over a mile long.

Tunnels are made in many cases, where, with us, they would be decided extravagances; but the circumstances are so different — what with the greater cost of the land, and the less cost of labor—that it is impossible as a mere looker-on to judge them. European roads use a greater depth of ballast than is common with us, though perhaps no more, except in rare cases, than is usual on our first-class roads, 18 inches being about the average. The profile of the ballast is generally level or nearly so for the whole width of the road-bed, the entire reliance for drainage being upon the porosity of the material used. German roads, including those of Austria (of which the practice is in the main the same) ballast up to the top of the tie; the English, half-way up the web of the rail, leaving at every third or fourth tie a cross-gutter between the ties; while the French ballast up to the bottom of the top rail-table, rounding the ballast on the inside of the track, however, so as to carry it down to the bottom of the splices at the rails, while remaining of the full height at the centre. The latter practice deadens the noise considerably, but is of course very inconvenient for "surfacing" track.

One is struck even in Germany, where railways are built in a more economical manner than in France or England, with the extravagance, as it seems to us, in certain ways, such as the use of skew bridges, for instance. In a short length of road, over an insignificant stream, one will see two or three skew bridges, where the stream could easily have been turned, to the avoidance of the extra expense. Another favorite and useless feature are the double-deck stone bridges to be seen in various parts of Europe, notably on the road over the Lemmering Pass, not far from Vienna. The engineers of these bridges seem to have been afraid of having the piers shaken down by the motion of the train, and have consequently built their bridges in two tiers of arches, the lower tier serving the imaginary object of preventing a flexure of the piers in the axis of the bridge, and having the disadvantage of detracting very much from lightness and grace.

The favorite iron bridge in Europe, even at the present day, is the lattice truss, with larger or smaller lozenges between the pieces. Wrought-iron is used almost exclusively—except for arched bridges—both top and bottom chords being built up of thicknesses of plate, with a double web at the bottom and top of the upper and lower chords respectively, between the plates of which the ends of the lattice are inserted, and thus secured by riveting to the chords.

The rail sections used on the continent are similar in the main to our own, but much heavier as a rule, and also higher in proportion to the width of the bottom flange, the modern German standard rail section

weighing from 75 to 85 pounds per yard, and being from $4\frac{3}{4}$ to $5\frac{1}{4}$ inches in height, with a base of about 4 inches, which weights and proportions are also about those of the most approved French practice. English rails are of about the same weight or a little heavier, but they are almost universally of the double-headed pattern. France has still a number of lines laid with double-headed rails, but the practice inclines to the other. The ties upon the continent are about 3 feet apart. Our practice of placing the ties nearer together equalizes somewhat the lighter weight of our rails.

European rails are generally symmetrical, the inclination for the coning of the wheel being given upon the tie; but in two cases of roads in Germany where new rails were being laid, the writer observed rails going down with the inclination in the head itself, which is, perhaps, an indication of the modern tendency. The more ordinary position on the continent for the notch to receive the spike holding the rail in position longitudinally is the middle of the rail, but since it has been so thoroughly proved that these notches diminish the strength of the rail to a great degree, it is hardly probable that this practice will continue in spite of its convenience as compared with notches at the end.

The split switch so commonly used upon our western roads is almost the only one used in Europe. The switch lever has no locking apparatus, but is kept in place by a counterweight upon a short movable arm nearly at right angles to the lever. The swinging of this arm a half circle around the lever brings the weight into place to hold the switch in one or the other position. This arrangement has the advantage of flexibility, so that the "running through" of a switch by a careless engine-driver does not throw any severe strain upon the apparatus. It would perhaps be hardly safe to apply it, except where, as almost universally in Europe, the switchman is constantly on hand to see that everything is right.

The gauges throughout Europe are, with few exceptions, 4 feet $8\frac{1}{2}$ inches. The most notable are of Spain and Russia, the former being 5 feet $8\frac{1}{2}$ inches, and the latter, 5 feet.

In Germany, the first item in the way of signals that strikes an American is the electric bell system used for communicating information or instructions of simple character to the watchmen who are stationed at more or less regular intervals—generally at level crossings—along the line. Each watchman's station is provided with a gong of large size, mounted upon a little building—or rather, upright box, containing the mechanism. The gongs, by the way, are generally double, and the notes are made harmonic, being said to be more effective for hearing than single bells. Upon all of these bells between any two stations, signals are made simultaneously by means of hammers striking the bells, operated from either terminal station. The signals given are few in number, the chief ones being the departure of a train from one or the other station, signaled by a different number of strokes. The effect of the striking of these bells is sometimes very pretty, particularly when heard from a high point, where those at several stations can be heard striking at the same time, the strokes coming to the ear, however, at different instants.

Many roads upon the continent now use an electric switch signal at either end of a station ground. This signal stands normally at danger. When, however, a train is expected and everything is clear, the switchman sets the signal at "all right," whereupon an electric bell is set in motion at the station, which rings until the train has passed, and the watchman has released the signal, which goes back to "danger." It will be noticed what a safe signal this is. Since it stands ordinarily at "danger" no train can enter the ground until the signal is set. If either the signal is not set, or the apparatus has fallen out of order, the station-master, not hearing the bell in action when the train is expected, investigates the matter. If, on the contrary, the signal does not go to "danger" after the train has passed, or if the apparatus gets out of order, so that the bell continues to sound, the station-master is equally warned. This apparatus is used upon a few roads with us, the Eastern R. R. of Massachusetts for one since the unfortunate collision at Revere, some years ago.

A little convenience for superintending engineers, road-masters, and others interested in knowing the rate of grade at different points of the line is to be found in the grade posts set throughout Europe, at the points of change, consisting simply of a post, rising any convenient height above ground (most commonly only a foot or two), with two pieces of board fastened to it like

the arms of a sign-post, which are, however, inclined to show the direction of the respective grades, and are marked with the rates of grade, and generally with the lengths of the respective inclines or levels.

Signals and crossing-gates, the latter generally being simply bars like old fashioned well sweeps, held open by a counterpoise on the short end, are operated at long distances, in some cases (at different ends of a tunnel for instance) as great as a mile or more, by wires running upon little rollers at regular intervals; a system which I believe is only to be seen upon our side of the water, upon Canadian roads, unless in some exceptional cases.

Traversing and turn-tables for transferring freight cars from one track to another are very much used; every station being provided with at least one transverse line of rails for connecting the various tracks. The transverse track on the same level with the main lines, and having turn-tables at its intersections with them, is the most popular, and is a decided convenience where a large staff of employés is on hand to move cars, but the much greater length of our cars, and the consequent increase in the expense of such apparatus will probably prevent its being adopted extensively in the United States.

There is one use of traversing tables, however, which has not fallen under the writer's observation in the United States, and which seems a very useful one in cases where economy of space in engine-houses is a consideration; that is, what is called the rectangular system. As practiced in France, where chiefly used, it consists in arranging the engine stalls upon parallel tracks in a building divided in the centre by a pit, with a transverse system of rails, carrying a transfer-table. Each of the parallel tracks gives two stalls, lying upon either side of the transfer pit, whose table, generally provided with a small steam-engine, gives the means of moving an engine from the entrance track to any stall, and vice versa. Under the system as practiced abroad, the pit is covered, which involves a great expense of roof over waste space—the chief defect of the system. If snow should not prove too great an obstacle, there would not seem to be much reason otherwise why the pit should not be left open, dividing the house into two separate ones. The system offers considerable advantages over lunettes or round-houses for repair engine-houses, in the greater facility it affords for setting up shafting or traveling cranes.

The lightness of the running gear of European rolling-stock strikes the American observer. Freight cars weighing but 10,000 pounds, carry 20,000 or even as much as 30,000 pounds; and although the proportion is generally far from being so favorable in the passenger stock, it is on an average, perhaps, even more favorable in comparison with our own. Some of the double-deck cars, which are quite common upon French roads, exhibit a most extraordinarily small proportion of dead weight. One on exhibition at Vienna, with a capacity of 90 persons, weighed only 11.75 tons. It would seem these cars might be made even lighter, were it not for the side buffing system, which throws heavy diagonal strains upon the floor frames. The secret of the thing must lie in the superior average character of European permanent way, and it is an interesting question, if, upon the gre t roads with us whose road-bed and tracks are nearly or quite as good as those of Europe, it is not possible to make some radical reforms in that matter, at least in passenger stock, which is not liable to wander upon badly kept roads.

The wheel-coning in Europe is generally $\frac{1}{20}$, the tendency being rather towards increase than diminution, some roads having made it as high as $\frac{1}{16}$, and $\frac{1}{17}$ having been found to give good results. The Vienna & Salzburg line tried the experiment of doing it away altogether, but it is conceded that the results are bad.

Brakes in Europe are seldom applied to more than a limited number of vehicles in a train. The French "Direction of Roads and Bridges" has declared the Westinghouse brake too complicated in its connection between cars to render its adoption probable upon French roads; a dictum rather astonishing to any one who knows how infinitely more simple the connection is than the ordinary European car-coupling, which involves the giving of at least half a dozen turns to a sort of vice-handle which has to be released and seized again at each turn.

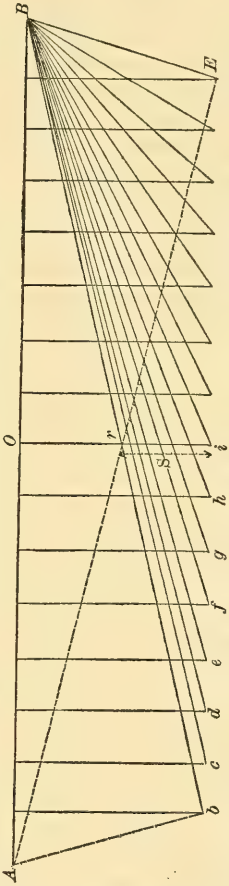
AN ERRONEOUS BRIDGE FORMULA.

Written for Van Nostrand's Magazine, by ERNST A. HARRIS, C. E.

In the January number of this magazine of this year, there appeared an article from F. W. Smith, pointing out discrepancies between two methods of calculating the stresses upon the main chord of a Bollman truss. In this article it was shown that a formula "given by Shreve Molesworth and others," gave the stress on the chord in a certain numerical example as 320 tons, while the method used by Trautwine, Vose, etc., gave the stress as 425 tons, making a very important difference. The article in question was headed "An Open Question in Bridge Building," and though it successfully pointed out the discrepancy above and indirectly inferred that the formula $\frac{W\,L}{8\,D}$ in this case = 320 tons, was erroneous, it did not show where, and appeared to leave the question partially undecided; speaking as if the error was due to the use of the method of moments round a point. The subject of this article is to decide the point in question, by showing that the formula $\frac{W\,L}{8\,D}$ is entirely erroneous; that the erroneous result obtained is not due to the use of the method of moments, but to a wrong assumption in the use of the method; that the method, when correctly applied, gives the same result as the other methods; secondly to examine another form of the Bollman truss, not touched upon by F. W. Smith, and for which an erroneous formula is also given.

To do this, it is only necessary to introduce the following axiomatic formula, from the eminent works of Prof. Macquorn Rankine.

Theorem,—"If a frame be acted upon by any system of external forces, and if that frame be conceived to be completely divided into two parts by an ideal surface, the stresses along the bars, which are intersected by that surface, balance the external forces which act on each of the two parts of the frame."



Only one system of diagonals is shown, those from each end cross $o\,i$ in exactly the same point in pairs.

To apply this theorem to the Bollman truss in the example in question, let W = total gross load; let L = span; let $\frac{W}{L} = w = w\,t$ per unit of length; let D = depth of the truss; let H = thrust along the chord A B. Let the distance at which any diagonal rod crosses the upright $o\,i$ from i be designated by s. Thus for A E, $r\,i = s$. Let the tension on any one of the rods, as L B, resolved into its horizontal component = t.

Take a section through the middle of the truss. The moment of the external forces acting on each of the two parts of the bridge about the section $o\,i$ is then given by the well-known formula of half the intensity of the load into the product of the segment of the line A B which reduces to $M = \frac{W\,L}{8}$ = moment at $o\,i$. Shreve now proceeds to place this = H D, because, says he, "Taking moments round the point (i) in the centre of the truss and in the line of the lower ends of the vertical braces, the strains in the inclined braces crossing the centre may be disregarded, as their amounts in opposite directions exactly balance each other, and we have therefore $H\,D = \frac{W\,L}{8}$."

Here is where the mistake is made; instead of the stresses on these braces crossing the centre, balancing each other about the point i, they being tension all act in the same direction around the point i.

The horizontal component of the stress on each rod is t, as there are two rods at each point, their moment around i will be $2 \Sigma t s$, where Σ denotes the sum of their moments. So that we shall have for the moment exerted by the bars at the section $o\,i$ H D $-2 \Sigma t s$, which must equal the moment of the external forces $\therefore$ H D $- 2 \Sigma t s = \frac{W L}{8}$. Hence for the example given by Shreve, where W = 240 tons, S = 160 ft., D = 15′, and taking the stresses along the diagonal rods as calculated by himself, we have the following table, by multiplying the stresses along each rod by the cor. of the angle it makes with $o\,i$.

Dis. from i or s for		Stress along	Horizont. Comp. of Stress.	Moment about i or $2\,t\,s$.
i B	0	40.71	40.00	0.0
h B	$\frac{6}{8}$	39.92	39.375	131.25
g B	$\frac{3}{4}$	37.92	37.50	225.00
f B	$\frac{14}{1}$	34.69	34.375	281.25
e B	5	30.23	30.00	300.00
d B	$7\frac{5}{12}$	24.54	24.40	281.25
c B	$\frac{99}{14}$	17.60	17.50	787.50
b B	7	9.42	9.38	131.25

Total or $= \Sigma\, 2\, t\, s = 1{,}575.00$,

which, substituted in the equation

$$HD - 2\Sigma ts = \frac{WL}{8}, \text{ or } \frac{WL}{8} - HD + 2\Sigma ts = o$$

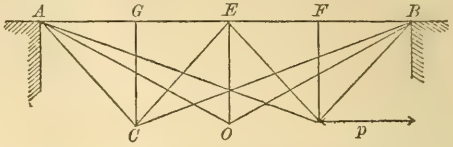
gives

$$\frac{240 \times 1^{6}0}{8} - H \times 15 + 1575 = o,$$

whence H = 425 tons, which shows that, if no wrong assumption is made, the method of moments brings out the correct result.

Another proof of this is given thus; by the theorem stated by Rankine. The horizontal stresses of the bars to the right of $o\,i$ must balance the external forces acting on the left or H $\pm \Sigma 2\, t\, s = o$, and if $\Sigma\ 2\, t\, s = o$ as Shreve assumed, then H = o, or there would be no stress along A B at all, a dilemma which cannot be escaped so long as it is held that the stresses along the inclined rods crossing the middle balance each other.

There remains another variety of the Bollman truss to be considered, which is given by Nystrom in his "Pocket-book of Mechanics and Engineering," edition 1872, page 303, of which the following figure is a representative.



Let L = span, W gross load; D = height of bridge; p = length of panel. H = thrust.

For this Nystrom gives the same formula

H or greatest thrust $= \frac{L W}{8 D}$

The following consideration will demonstrate the erroneousness of this formula.

In the first place, let us use again the axiomatic theorem stated by Rankine and take a section to the right of E O, and indefinitely near it. Then for equilibrium round o the sum of the moments of all the forces acting round that point must be zero. The bending moment is as before $\frac{L W}{8}$. The moment of H round o is H D, and the moments of the stresses on the rods around o will be as before $\Sigma t\ s$, so that we have, as before, $\frac{L W}{8} - H D + \Sigma t s = o$ $\therefore H = \frac{L W}{8 D} + \Sigma t\ s$.

This will give the same value to H as in the other variety of the truss, which is thus proved.

A certain portion of the weight at C goes to B, by means of C E; call this $\frac{W}{a}$. Its horizontal component $= \frac{W}{a}$ ten GCE $= \frac{W}{a}\frac{p}{D}$. Its moment about $o = \frac{W}{a}\frac{PD}{D} = \frac{W}{a}p$

Now let us suppose that this weight $\frac{W}{a}$ goes over C B instead of C E. Its horizontal component $= \frac{W}{a}\ \frac{3p}{D}$ and its moment about $o = \frac{W}{a}\frac{3p}{D}\frac{D}{3} = \frac{W}{a}\ p$, so that the value of $\Sigma t\ s$ is not altered whichever way the weight goes, and therefore the value of H is the same as if all the weight at C went by way of C B 2 E D.

The same thing might be shown by the resolution of forces, thus H or comp. of $\frac{W}{a}$ over C E $= \frac{W}{a}\frac{p}{D}$ horizontal comp. $\frac{W}{a}$ along O B $= \frac{W}{a}\frac{2p}{D}$. Sum $= \frac{Wp}{aD}$

$+\frac{W}{a}\frac{2p}{D}=\frac{3}{a}\frac{W}{D}\frac{p}{}$ but this is the horizontal component of $\frac{W}{a}$ over C B.

It is evident, therefore, that a dangerous mistake is made, by using the formula which is the subject of this article.

[Note by the editor. That the horizontal stress in the chord of a Bollman truss depends upon the number of panels, and that the value of this stress lies between $\frac{W\,L}{8\,D}$ and $\frac{W\,L}{6\,D}$ may be shown in the following manner: Employing the notation of this article, and using n for the number of panels,)whence $\frac{L}{n}$ = length of one panel), we have

$\frac{W}{n}$ load at b

$\frac{W}{n}\times\frac{n-1}{n}$ = portion of this load conveyed to A.

$\frac{W}{n}\times\frac{n-1}{n}\times\frac{L}{n\,D}$ = horizontal stress arising from this load.

$\frac{WL\times(n-1)}{n^2D}$ = ditto.

The load at c is the same in amount, but $\frac{Wn}{u}\times\frac{n-2}{n}$ = portion of load conveyed to A, and

$\frac{W}{n}\times\frac{n-2}{n}\times\frac{2\,L}{nD}$ = horizontal stress arising therefrom.

$\frac{WL}{n^2D}\times\frac{2(n-2)}{}$ = ditto.

The sum of all these forces is evidently

$\frac{W\,L}{n^2\,D}\left((n-1)+2(n-2)+3(n-3)+\ldots n(n-n)\right)$

which reduces readily to

$\frac{W\,L}{n^2D}\times\frac{n^2-n}{6}=\frac{W\,L}{6\,D}\left(1-\frac{1}{n^2}\right)$ the total horizontal stress on the chord.

When $n=2$, the smallest admissible number, then the thrust is $\frac{W\,L}{8\,D}$.

When $n=\infty$ the thrust becomes $\frac{WL}{6\,D}$]

REPORTS OF ENGINEERS' SOCIETIES.

THE AMERICAN MASTER MECHANICS' ASSOCIATION.—The seventh annual session of this Association was held in Kingsbury Hall, Chicago, beginning on May 12th, and the three days following.

The President, Mr. H. M. Britton, in his very able address respecting railroads and the grangers, observed:—Involved in the question of operating the rolling stock, for which you are directly responsible, is the cost of moving large bulks great distances, and selling them at a profit. All the injury to the railroad interest of the country which a misconception of this great question could do, has been worked within a year. It is hardly possible to overestimate that injury. It had its origin in something akin to fraud, perpetrated by those who projected and constructed railroads, on the people of neighborhoods through which they passed. To obtain from the farmer pecuniary aid in way of donations, by representing to him that his bulky freight, in the shape of farm products, would find a high market, and a low rate of freight, was one unfailing financial resource of the projectors of these unnecessary roads. It was the hope held to the view of the honest and unsuspecting husbandman, built upon a foundation of misrepresentation and falsehood. It has borne the bitter fruit which might have been foreseen. The deceived farmer, finding the rate charged by the railroad did not bring him the promised market for his products, became a granger, the granger became a legislator, and treated the railroad interests of great States with arbitrary laws and enactments. To regulate trade, not by the law of supply and demand, not by the cost of doing the business, but by legislative enactment; to say that a railroad shall haul a ton of freight for one-half a cent when the absolute cost of hauling is one cent a ton, is as if you should require the farmer to sell his corn at twenty-five cents a bushel when he can realise fifty cents by feeding it to hogs; or, as if you should legislate him into a sale of his hogs at some particular place in the State at half their market value. This seems absurd enough; nevertheless, the granger, deceived into donating his money to build the railroad, legislates with the passion of resentment, not with the wisdom which follows calm reflection. In Wisconsin, the railroads complain that this legislation amounts to a confiscation of the railroad property. What doubt, what distrust, what absolute ruin overhangs a great commercial interest, thus threatened by hostile legislation!

The committee on the operation and management of locomotive boilers presented a very long report. The report discussed:—1. Incrustation; its causes, effects and cures. 2. The deposit of sediment; its effects and remedy. 3. The impurities in water which produce priming; its effects and only remedy. The committee reached the following conclusions:—That owing to the fact that no panacea could be found for all the incrustation diseases, it is evident that if it is to be cured by remedies at all, a diagnosis of each case must suggest the proper treatment.

The committee on the best form of safety-valve, or methods of relieving boiler overpressure, and the best way of testing pressure gauges, presented a report, in which the expression of opinion in regard to direct spring valves was, with few exceptions, in their favor. The grounds for this preference were stated to be their compactness and simplicity, the quick relief which they afford to an excess of pressure, their prompt closing when the pressure falls, and the fact that they are or may be made independent of the control of the engineer.

The report of the committee on a mechanical laboratory embodied in elaborate detail the following apparatus:—Adjustable model of valve motion; machine to test tensile, torsional, and com-

pressive strength of metals; machine to test friction of metals; machine to test lubricating value of oils, &c.; steam-engine indicator, with full diagram apparatus; most approved speed or revolution counter; pyrometer for testing high boiler temperature; thermometer with long range; vacuum gauge for use in locomotive smoke-boxes; mercurial column for testing steam-gauges; registering dynamometer for obtaining train resistances; microscope for the examination of metals; means of testing calorific value of different classes of coal, and principle of their most economical combustion; means of testing various qualities of water; means of testing acids in tallow under high temperature; means of testing incrustation compounds, and discovering their injurious ingredients when any; means of testing composition of specimens of boiler scales, &c.

The committee appointed to prepare subjects for discussion at the next meeting prese ted the following:—The best material, construction, operation and management of locomotive boilers; purification of feed-water—what methods up to this time have been most approved for the improvement of feed-water by chemical and mechanical means, and for the prevention of incrustation; locomotive tests—this committee to request members to make experimental tests to show the performance of locomotives, and to report the results to this association; locomotive construction—this committee to report as far as possible all new methods of construction which have been adopted by members during the past and ensuing year; the best system of signals for operating railroad trains, including train head signals, train tail and side signals, road or station switch signals, and appliances for indicating the speed of trains; locomotive and tender wheels—this committee to report breakages of wheels and tires, removals of tires, and causes of breakage or removal, and to report on the different methods of construction and manufacturing of various kinds of engine and tender wheels; construction and improvement of continuous train breaks during the ensuing year, and their application to cars and locomotives; lubricants for locomotives; mechanical laboratory; finance; trustees of Boston fund; printing; general supervisory.

The Committee on Valves and Valve Gear presented a long report. Fourteen members responded to the circular sent out by the committee, from which the following conclusions are deduced:—Of the fourteen members answering to the circular, four report in favor of balanced valves, and six against, while nearly all agree that there is a reduction in wear of seats and gear and increased ease in handling. The grounds of objection are liability to blowing and difficulty of keeping in repair. The mileage of the balanced valve, where comparisons have been instituted, is considerably in its favor, as against the flat valve. Seven replies are in favor of decreasing the size of parts from their experience, and two offer simply an opinion against reduction.

The Committee on Tires having presented its report, say:—The superiority of steel tires having been already demonstrated, all that remains to be determined is, which is the best tire, and how thin steel tires can be worn with safety. As it will take time for the steel tires now in use to wear out, we are not likely to obtain the desired information in regard to either of those points for some time to come. The whole number of sets reported on is 359. Upon the subject of setting and fastening steel tires, of the fifteen companies reported, ten use shrinkage alone, two use shrinkage and set-screws, and three use set-screws alone. The amount of shrinkage allowed is:—Five allow 1·100 inch to 1 foot in diameter of wheel; one allows 1-32 inch to a 5-foot wheel and less in proportion: one allows 1-80 inch to 1 foot in diameter of the wheel if soft, and less if it is hard; one allows 1-20 inch to a 5-foot wheel; one allows 1-16 inch to a 5 and 4½ foot wheel he secures by a screw; one allows 82-1000 inch to a 5 and 5½-foot wheel; one uses set-screws 1¼ inch in diameter, and allows shrinkage 1-16 inch to 5½-foot wheel, and the same proportion to a 4½-foot wheel; one uses set-screws and allows 1-32 inch shrinkage to a 4½-foot wheel; one uses lap bolt through felloe of wheel, countersunk 3-8 of an inch in the tire. The Great Western of Canada uses set-screws with thread of screw run 7-8 of an inch into the tire, but has no thread cut in that part of the screw which passes through the rim of the wheel. The reports indicate that chilled tires will average about three years in durability; the lowest thickness of tires at removal was 3-16 inches, the average about 1½. Steel driving-axles and truck wheels were generally preferred. The Great Western of Canada prefers axles of good hammered iron.

The Committee on Standard Axles presented their report, in which they recommend the following proportions for freight and passenger car and tender axles:—Total length over all, 6 feet 11¼ inches; journal, 3¾ inches in diameter, by 7 inches long; wheel 4 7-8 inches in diameter by 8 inches long; diameter in centre, 4 inches; color, 4¾ inches in diameter, by 5-8 of an inch thick. The committee are of opinion that owing to the great diversity in the construction of locomotive engines, no standard for the form and proportions could be adopted in the construction of the axles, without first making important modifications in the design and dimensions of other parts of locomotives.

The Committee appointed to report on Oils for Locomotive Use, came to the following conclusions from communications received:—The majority recommend the use of No. 1 extra lard oil, while others insist that it caused rust, and declare that sperm oil is the proper thing. The use of mineral oil is condemned, but plumbago faintly recommended. As to water used, it was thought more lubrication was needed where hard water was the supply.

Mr. Wells, Chairman of the Committee on Continuous Train Brakes, read a report of great length. Replies to their circular had been received from twenty roads. Of these three only use hand-brakes, fourteen the Westinghouse air-brake. The theoretic requirements of a perfect continuous train brake were declared to be as follows:—Certainty of instant application to all or as many of the wheels of the train as practicable; the retarding power should be capable of being graduated at the will of the person applying it, under all ordinary circumstances; when applied from any cause, it should so remain until the train is brought to a stop, unless persons in charge of it desire otherwise, in which case it

should be capable of instant, partial, or total release; the brake power should be under the control of the engineer of the train; it should apply itself in case of derailment of any part of the train, or in case the train should part accidently, and should be capable of application from any car in the train at the will of the person thereon, when necessary.

The Committee on Machinery for supplying Water to Tanks recommended the use of a natural fall to get water into the tank where practicable; windmill, where the formation of the country will permit. Next, steam power.

The election of officers was postponed for one year, allowing the present officers to hold another term. The principal being the president, Mr. H. M. Britton, of Cincinnati, and the secretary, Mr. J. H. Setchel, of Cincinnati.

The Convention adjourned, to meet in New York on the second Tuesday of May next year.

ENGINEERING STRUCTURES.

FIRE-PROOF FLOORING.—As bearing on the subject of so-called fire-proof buildings, now being considered in our columns, we think it will prove of interest to refer to some experiments recently carried out at Erith at the works of Messrs. Easton & Anderson. We have already dwelt upon the fact that wrought iron as commonly employed to resist the action of fire, and even when protected by concrete, has shown itself to be entirely unreliable in fire-proof structures. It is, however, well known that fireclay forms a much more efficient material for protecting wrought iron from the destructive action of intense heat, and it is with the application of this material by Mr. J. Whichcord, the engineer to the National Safe Deposit Company, that such good results were obtained the other day at Erith. The arrangement consists merely in employing a number of fireclay blocks about nine inches long, and from one and a half to two inches thick, formed on one side with recesses of an L form, so as to fit closely to the web and bottom flange of the wrought-iron girder. The outer sides of the blocks can be made of any desired form to receive ceiling arches or joists. The blocks being placed upon the girders, meet underneath the bottom flange, and the longitudinal as well as the transverse joints are made good with fireclay. Returning to the experiments at Erith. A furnace fifteen feet long and four feet wide in the clear was constructed, and across the top a rolled iron joist of I section, seventeen feet long, ten inches deep, and with five inch flanges, was laid spanning the length of the furnace. This girder was protected with blocks in the manner above described, and on each side of the girder, brick arches were built abutting against the side walls of the furnace. Over the top of the arches and girder a thickness of concrete was laid, and the floor thus formed was loaded with pig iron, to one-fourth of its breaking weight. After the structure was thoroughly dried, a fierce wood fire was made up in the furnace, and was maintained for two and a half hours, when large quantities of water was thrown on the heated mass. The deflection of the loaded girder had when heated amounted to one and a quarter inches, but when the weights were removed, and the beam had cooled, the deflection disappeared, and it remained apparently uninjured, although the fireclay sheathi was vitrified on the surface.

A second experiment was made on the 28th ult., when a fierce fire was kept up for one and half hours, and then maintained moderately for twenty-eight hours more, after which it was suddenly extinguished with cold water. The deflection of the loaded girder had been 3-32 in. at the commencement of the trial and reached a maximum during the fire of 1 3-16 in., reduced to 3-8 in. when the load was removed, but before the beam was cold. Ultimately, however, it returned to the original amount of 3-32 in.

Altogether this experiment, which was carefully carried out, shows the enormous resisting power of the fireclay blocks, and it may be mentioned that one end of the girder which projected through the brick work of the furnace was quite cool, when the fire was at its hottest, and no appreciable expansion was observed. The beam will be employed in the building for which it was originally intended.

OPENING OF THE ST. LOUIS BRIDGE.—CHARACTER AND DIMENSIONS OF THE STRUCTURE.

ST. LOUIS, Mo., July 4, 1874.

The formal opening of the Illinois and St. Louis Bridge was celebrated to-day with great enthusiasm. The display was finer than ever before witnessed here. The procession was five hours in passing a given point. Addresses were made by Mayor Brow, ex-Senator Gratz Brown, Governor Woodson, of Missouri, and Governor Beveridge, of Illinois.

DESCRIPTION OF THE BRIDGE.

The completed bridge is of three spans of 497, 515 and 497 feet respectively in the clear, each span formed with four ribbed arches of cast steel. The double rib enables the arch to preserve its shape under all circumstances of unequal pressure on its parts and obviate the necessity of a spandrel bracing. The spans rest on piers of granite and concrete, built on the bed rock of the river. The upper roadway is fifty feet wide between the railings, two foot-walks, each of eight feet, and a road-way of thirty-four feet, occupying the space. Below the carriageway are the railway passages, each thirteen and a half feet in the clear and sixteen feet high, extending through arch openings of the same size in the piers and abutments. On the other side of the river five stone arches, twenty feet wide, carry the railways over the levee and wharves; they are enclosed by a cut stone arcade of twenty arches, supporting the upper roadway. Brick arches conduct the railways into the tunnel at Third street and along this, upon a six foot bed of macadamized stone, the trains will run to the Union depot. The carriageway runs on a level to Third street. On the Illinois side the carriage road descends with a grade of five feet in 100, while the railway tracts curve off north and south over the approaches of trestle work, with a descending grade of one in 100, till at a distance of 3,000 feet they reach the level of the Illinois roads. At its lowest point, in accordance with the requirements of the federal law, the bridge is fifty feet above high water mark. From the roadway it is at present between ninety and 100 feet from the surface of the river.—*Herald.*

IRON AND STEEL NOTES.

Communication Relative to Converting Pig Iron into Steel by Berard's Process. By M. Aristide Berard, Paris. The author is the inventor of a process for the direct conversion of pig iron into steel by using gases in a reverberatory furnace with movable bottom placed in a peculiar manner. By means of an oxidizing or reducing action, regulated at will by the operator, and acting in the metal bath by the help of dipping tuyeres, the decarburation of the pig iron is moderated with mathematical precision, and the waste reduced to a minimum. The puddling, in a measure mechanical, effected by the blowing in of air and gases bringing constantly together the metal and slag, facilitates the elimination of foreign bodies injurious to the quality of the steel (such as sulphur, phosphorus, &c.), allowing thereby the use of pig iron of an inferior quality in obtaining certain products. By the means adopted for the production of gases as well as for their application, the exceptionally high temperature is developed which is indispensable for the production of certain qualities of steel. The steel obtained from this high temperature, and under the action of hydrogen, without the injurious effects of an oxygenous cementation, has special qualities of resistance, malleability, and welding. Under the aforesaid conditions of manufacture, steel ingots may be obtained easily at the price of iron.—*Journal of Iron and Steel Institute.*

Production of Highly Silicised Pig Iron. Since our last report, in which we gave an account of Professor Jordan's researches on this subject, a paper entitled "Researches on cast irons rich in silicon," has appeared in the Annales des Mines, for 1873, in which the authors give the results of their investigations into the behavior of compound of iron with silicon under various circumstances, showing that the reducing action of the carburet of iron on silica is a very slow one, and that it is interfered with by basic slags, their experiments having proved directly that when a silicious cast iron is melted with lime or with a very basic silicate of lime, silicon is removed from it. They also consider that one of the causes of the formation of cast iron containing much silicon is the presence of alkaline silicates in the furnace, and state that a mixture of carbonate of potash, charcoal, iron filings, and silica, when melted in a blast furnace at a high temperature, will at once afford a cast iron containing as much as from 15 to 16 per cent. of silicon, along with 2.94 per cent. carbon, a result which they consider due to the reduction of potassium, which by re-acting in its turn on the silica, sets the silicon at liberty to combine with the iron.—*Journal of Iron and Steel Institute.*

Influence of Titanium in Iron Smelting.—As it is well known that cast irons made from most ores containing titanic acid, do not themselves contain any, or only a trace of titanium, the precise reason why this substance should have this beneficial influence on the quality of the iron or steel made from such ores, which is generally ascribed to it, is somewhat difficult to explain. In the Jern-Kontorets Annaler, it is stated that it is common in Sweden, when the iron ores are sulphury, to add to the charge titanic iron ores (containing less than 10 per cent. titanium), which, it is asserted, prevent the iron produced becoming red short, possibly, it is imagined, owing to the formation of compound of sulphocyanogen with titanium; as yet, however, there is no evidence to prove that titanium has the same influence on the smelting of ores containing phosphorus.

Action of Slag on Fire-Clay. The results of an experimental inquiry into the behavior of different fire-clays when in contact with iron blast-furnace slag at high temperatures has been published in Dingler's Polytek. Journal, cciii., p. 445–450, by Carl Bischof. The experiments were made by mixing the fire-clays with the desired proportion of powdered slag, and moulding it into a small cylinder which is exposed to the heat until it loses shape. With Hessian fire-clay, 1 per cent. of slag is sufficient when the temperature is as high as the fusing point of platinum. Gruenstadt, Muelheim, and Belgian fire-clays required from 5 to 7 per cent.; Laaren No. 2 fire-clay, 6 per cent.; Garnkirk, 8 per cent.; Laaren No. 1, 13 per cent.; and Zellitz fire-clay, 14 per cent. Of course, these results are merely comparative, since blast-furnace slags vary greatly in chemical composition; and in trials made with two different slags, one produced along with grey Bessemer pig iron which contained 54 per cent. of lime, and the other from white iron, with 41 per cent. of lime; the latter exhibited less tendency to make the fire-clay fusible.—*Iron and Steel Institute.*

RAILWAY NOTES.

Abolition of the Broad Gauge.—During Friday, Saturday and Sunday last, the Great Western Railway Company has converted its south-western lines from the broad to the narrow gauge. The work began at daybreak on Friday morning, and the following account shows the magnitude of the task and the precautions which had to be taken:

For some days previous to commencement of the work, the broad gauge stock was gradually worked off the line, and on Thursday evening each station-master had to give a certificate that his station and district was clear of broad-gauge rolling stock, the last trains of which arrived at the Chippenham end of the line about midnight, and were sent to appointed depots. Immediately afterwards the line was handed over to the engineers, who were entrusted with the supervision of the work between Chippenham and Weymouth, Bathampton and Weymouth, and various branches in connection, the largest of which was that from Witham to Wells. About 2,000 men were engaged on the work, the company having concentrated a number of men on various sections of the work. Each man received 1s 3d. per day for rations, and the company found oatmeal and good water for making a wholesome and strengthening beverage. Sheds were also erected where sleeping accommodation was scanty, and the men worked seventeen or eighteen out of each twenty-four hours, their energy and steadiness being remarkable. The scene along the whole of the line was a most busy one.

The *modus operandi* was as follows:—Only one rail on each line was moved; but for some weeks past the men have been engaged in clearing out the ballast to facilitate the shifting of the wood and ironwork, and also in partially sawing off the

'transoms." Where the rails were laid on "chairs" and "sleepers," additional chairs have been placed, so that the rails had to be simply moved from the old to the new set of sleepers and secured. In cases where the rails were fastened to longitudinal timbers, the partially sawn transoms were completely severed, and the rail and baulk pushed into the proper gauge and fastened. The men wore numbers, and worked in small parties, and the conversion was effected with surprising rapidity. Where double lines existed, as was the case over a material portion of the distance, the work was, of course, doubled. The greatest possible precautions were taken during the few days previous to the commencement of the work in order to prevent accidents. Pilot men wearing badges, and each carrying a written authority, were attached to the engines working on single lines. These officials were responsible for the safe working of the line, and were instructed to tell their drivers to diminish speed at certain points where any supposed weakness existed. The same will be the case on the resumption of traffic.

The narrow gauge is also down between Bath nd Bristol, and will be opened simultaneously.

A Railway up Mount Vesuvius.—The *Liberta* of Rome describes the model of a "funicular railway," the concession of which has been applied for to the Italian Government by a company that proposes to construct it up to the crater of Mount Vesuvius. The model consists of an inclined plane, presenting a gradient of thirty-three per cent., with a double line of rails, one for going up, and the other for the descent. The engine, which is fixed at the bottom of the plane, sets two drums in motion, round which the metallic cable is wound by means of which the trains are drawn up and let down simultaneously. This plan appears to be preferable to the rack-and-wheel system used for the ascent of Mount Righi, both as to the working and cost. The section, to the slope of the mountain at San Guiseppe, is to be performed by common locomotive, the rope is then put on, and the ascent commences by the new plan. The whole length of the railway will be sixteen miles; the time required between Naples and the crater is calculated at an hour and a quarter, and the whole cost of the line is estimated at four millions of francs. The funicular system is of course no new invention—the improvements lie in the details. The company are very sanguine as to the results; they say that as upwards of 40,000 travelers annually ascend the Righi for the sake of its fine view, they may expect more to go up Mount Vesuvius, which owing to the sea, offers a far more magnificent view.

The Bombay, Baroda and Central India Railway Company have been engaged during the past year in preserving the stability of the bridges. Their engineers have been successful in screwing additional piles into the beds of the rivers to a far greater depth than was originally thought necessary, and they hope, therefore, to secure the stability of the piers in the extensive rivers they cross. The sheds for the protection of fuel have recently been considerably extended; they are now completed at five of the principal stations on their line. The Dakore branch, 16½ miles in length, was opened on the 8th of April last for passenger traffic, and for goods traffic on the 20th of that month. The branch has been constructed on the standard gauge of 5½ft., and with rails of 60lb. to the yard; the cost, exclusive of rolling stock, has been only £4,000 per mile, which is thought to be very creditable to the company's engineers. The State line is being extended from Delhi to Ajmere, and it is of great import, ance to the company that the line should be extended from Ahmedabad to Ajmere to complete the communication from Bombay to the Northwest Provinces. The company have proposed to make thaportion of the line on any gauge the Government may deem expedient. The Company's engineert have constructed three tank engines in the works shops at Bombay, and they are much admired for the completeness of their construction. They have also aided the Government in the supply of 500 goods wagons to meet the requirements of the famine.

BOOK NOTICES.

Tri-Nitro-Glycerin as applied in the Hoosac Tunnel. By George M. Mowbray. New York: D. Van Nostrand. Price, $3.00.

Besides the history of experiences at the Hoosac Tunnel, this work of an experienced chemist treats fully of the methods of manufacture and the conditions of proper use of Nitro-Glycerin, and other explosives derived from it.

The author says: "Since the introduction of this explosive as a substitute for gunpowder in the Hoosac Tunnel, accidents from explosion have diminished two-thirds of the previous average rates, progress has advanced from the rate of sixty-one feet per month in September, 1868, under State supervision, to four hundred feet per month in September, 1873, under contract; being six-fold; and in February, 1874, tri-nitro-glycerin delivered at one dollar per pound, possessing an admitted force of ten times that of the best mining powder, is a reduction in cost of explosive force, in favor of nitro-glycerin, of over thirty-three per cent. * * * Add to this that nitro-glycerin will blast out holes four times the depth of powder-charged holes, and the saving of time in removing and replacing the drilling machines is apparent, and its usefulness to the contractor indisputable."

Several full page illustrations embellish the work.

Earthwork Mensuration on the basis of the Prismoidal Formula. By Conway R. Howard, C. E. New York: D. Van Nostrand. Price, $1.50.

It seems to be universally conceded that in earthwork calculations, methods based on the prismoidal formula only should be employed. "Average" and "Mean Average" methods are too inaccurate for even the most simple cases; moreover the percentage of error is so variable for the different commonly recurring conditions that such approximate methods are doubly unsatisfactory.

In employing the Prismoidal Formula three plans of working are open to the computer.

1st. The direct application of the formula to each case; involving the determination of mid-way section in each prismoid. 2d. Employing carefully

prepared tables. 3d. Using the graphic method, or rather charts in which linear intersections point to tabulated results. We confess a strong preference for the second plan. The first plan is of course free from any suspicion of error, but it involves an unnecessary expenditure of time, inasmuch as in successive prismoids with similar slopes and bases, much work is repeated. Well directed efforts to save this loss of time lead directly to the employment of the second plan; and it is a conspicuous merit of the work before us that the method of calculating the tables is so clearly and concisely set forth, that no one capable of using any method safely can fail to understand how to prepare such tables as these, or to extend the set in the book to any desired limit.

The third plan referred to above is employed by many who desire to reduce the use of numbers to a minimum. Trautwine's Tables afford the best known example, and are widely used. For beginners in field work, whether students in scientific schools or engineers of fresh experience, the methods involving the construction and use of tables seem to us far preferable to any others. For such Mr. Howard's book is sufficient.

REPORT ON THE EFFECTS OF THE SEA-WATER AND EXPOSURE UPON THE IRON-PILE SHAFTS OF THE BRANDYWINE-SHOAL LIGHT-HOUSE. By Lieut. Col. JOHN D. KURTZ and Capt. MICAH R. BROWN. Washington: GOVERNMENT PRINTING OFFICE.

This report affords minute details of the examination of a system of Iron Piles, seventy-seven in all, which have been exposed to the action of sea-water for periods varying from sixteen to twenty-five years. The measurements made of the diameters of the piles at different levels are carefully tabulated. A valuable addition to the literature of practical engineering.

CANADIAN PACIFIC RAILWAY—REPORT OF PROGRESS ON THE EXPLORATIONS AND SURVEYS. By SANFORD FLEMING, Engineer-in-Chief. Ottawa: McLEAN, ROGER & Co.

This report will be read with interest by many who feel no concern about the feasibility of the proposed railroad, and as if to satisfy the wants of such, the report is replete with information about the territory surveyed. The maps, which are quite numerous, are drawn upon a large scale, and afford an important addition to the geography of our country.

COAL AS A RESERVOIR OF POWER. By ROBT. HUNT, F. R. S.

ATOMS. By PROF. CLIFFORD, M. A. Boston. ESTES & LAURIAT.

These two essays together form No. 11 of "Half-Hour Recreations in Popular Science."

The first is an elementary exposition of the laws of heat, or rather of the laws governing the generation of heat from combustion.

The second essay is the longer one and by far the more abstruse; the illustrations employed by the author to elucidate the properties of matter when in the gaseous condition seem to us peculiarly apt and forcible. In these Half-Hour Recreations much sound knowledge may be obtained.

ON A NEW METHOD OF OBTAINING THE DIFFERENTIALS OF FUNCTIONS, WITH ESPECIAL REFERENCE TO THE NEWTONIAN CONCEPTION OF RATES OR VELOCITIES. By Prof. J. M. RICE; U. S. Naval Academy, and Prof. W. W. JOHNSON, St. John's College. Cambridge: Welch, Bigelow & Co.

This is a pamphlet of twelve pages only, but presents an introduction to the differential calculus which many learners will prefer to either of the methods usually employed. The writers are evidently both familiar with methods of instruction, and have presented the subject in a form adapted to beginners in the subject; although the work as submitted is for those who have progressed beyond this entrance gate to the higher analysis, and it is evidently designed that instructors may enjoy the benefit of commanding for their pupils another approach to the heights which the majority attain only with difficulty.

The essay deserves wide circulation.

THE ELEMENTS OF ALGEBRA. By F. A. SHOUP. New York: E. J. Hale & Son. Price, $1.50.

The author has compressed the usual course of Algebra as far as Logarithmic Series into small compass without omitting any important topics. The Expositions are very concise and the examples under each topic few in number. The work affords good suggestions to the instructor, and will prove of more use to teachers, we judge, than to learners. The book is in a very neat form and invites by its appearance a close acquaintance.

A MANUAL OF INORGANIC CHEMISTRY. The Iron Metals. By T. E. THORPE F. R. S. E. London and Glasgow, Wm. Collins, Sons & Co. Price, $1.50.

This neat little volume is simply an expansion of the first portion of Elementary Inorganic Chemistry to a little more space than it generally occupies in our School Text-books. The nomenclature is of the new system, of course, and the exposition of the method of establishing the atomic weights is very clearly rendered.

There are no questions nor problems, but this lack may be supplied in the second part, which is to treat of the metals.

SHORT LECTURES ON SANITARY SUBJECTS. By RICHARD J. HALTON, London: Bailliere, Tindall & Cox. For sale by Van Nostrand. Price $2.50.

The subjects of the lectures, twelve in number are: 1st. The Necessity of Sanitary Science. 2d, Air. 3d, The Sick Room. 4th, Ventilation. 5th, The Relation of Popular literature to the Public Health. 6th, Food. 7th, Clothing. 8th, Cleanliness. 9th, Training and Education of the Young. 10th, Epidemics. 11th, The Influence of Amusements on the Public Health. 12th, Overcrowding.

The lectures are of an exceedingly practical character, and emanating as they do from an author who holds many prominent positions in leading institutions, they cannot be regarded as otherwise than very valuable.

THE PRACTICAL ASSAYER. By OLIVER NORTH. London: Chatto & Windus. 1874. For sale by Van Nostrand. Price, $3.75.

This work contains easy methods for the assay

of the principal metals and alloys, and it is principally designed for explorers and those interested in mines. It provides for a want that has long been felt,—a knowledge of practical modes of assaying, without any general or extensive knowledge of analytical chemistry. Assaying is a mere mechanical art, and some of the best and quickest assayers have been mining youths who could hardly write their own names and were not analytic chemists at all. All hard words and formulas have been left out, and only easy and useful methods, which do not need expensive apparatus, have been given, so as to be useful chiefly to the mining explorer.—*Builder.*

"THEORY OF THE STRENGTH OF MATERIALS, illustrated by applications to Machines and Buildings," by Francis L. Vinton, C.M.C.E., Professor of Civil and Mining Engineering, School of Mines, Columbia College. New York. D. Van Nostrand. Price $3.00.

These notes were originally prepared for the course of Machine and Mining Engineering, in the School of Mines, Columbia College. The author has added to these, during the printing of his MSS. such other notes on Civil Engineering, as had then been introduced into the school. Consequently the arrangement of subjects is not altogether as he would have desired, and it is intended in future editions to remedy this defect. No tables have been introduced, because in the view of new experiments now prosecuting at the School of Mines and elsewhere, upon American material, the old tables have become comparatively worthless. The work will be found to be invaluable to engineers and students.

AN INTRODUCTION TO THE SCIENCE OF HEAT. By T. A. Orme. Third Edition. London: Groombridge & Sons, 1874.

This manual is intended for the use of schools and of candidates for university matriculation examinations, and as heat is now placed on an equal footing with dynamics and statics in the matriculation programme of the London University, it will prove specially useful in the preparatory studies of that institution. The use of arithmetic instead of algebraic formulæ throughout the work makes it suitable for the higher classes of schools, and the arithmetical accuracy to which the phenomena have been reduced render the science of heat peculiarly well adapted for study in superior seminaries.

THE GUN, RAM AND TORPEDO. London: J. Griffin & Co. For sale by D. Van Nostrand. Price, $4.25.

It was fortunate for the honor of the British navy that when the Shah inspected the twenty-five ironclads at Spithead, they were safe at anchor; for if any admiral knew how to lead such a fleet of dissimilar ships into action, it is certain that few of the twenty-five captains could have executed the necessary manœuvres. Much credit is due, therefore, to the Junior Naval Professional Association for offering a prize of fifty guineas for the best essay on the tactics of future naval battles. The result is this volume containing three essays treating the subject from three very different points of view. In the almost entire absence of exact data, speculation, opinion and assertion, find far too prominent a place in them, showing how exceedingly defective all naval education and training is in the art of war. "From a general point of view," writes the talented author of the second essay, "the subject has been systematically neglected and discouraged, and the few who have attempted to investigate its rules have been looked on as wild theorists. Opinion in respect to this is now happily changing; it is no longer held to be unprofessional, unseamanlike, un-English, to know anything about the conduct of a fleet, or to have ideas extending beyond holystones or scrubbed hammocks." As a sample of historical study and accurate reasoning, this second essay will probably outlive the first or prize essay; but for the present needs the rough guesses and bold assertions of the latter give it a greater temporary value. If we regard them simply as essays or attempts to solve a problem without data, they will do much good by indicating its difficulties, and by pointing out the necessity of employing our officers and our squadrons in time of peace in efforts to discover the uses in war of their ships, their guns, their rams, and their torpedoes, instead of concentrating their energies on useless fopperies and frivolous labors resulting in nothing higher than spotless decks, polished guns and symmetrical clothes' lines. The naval architect should study this volume if he would thoroughly appreciate the influence of his art on the conduct of fleets, and the primary necessity of quick turning powers in efficient war-ships. It is, indeed, the rapid revolution in naval architecture which has discomfited seamen in tactical knowledge, and makes them so ignorant of the efficient use of their weapons. If this volume lays this ignorance, its chief work will have been done.

MISCELLANEOUS.

MAGNIFICENT PROJECT.

A bold and splendid project, and one the successful accomplishment of which would bring enough of the glory it loves to satisfy even *la grande nation*, has been laid before the Geographical Society of France, and approved by that learned fraternity. It is no less than to add another sea to the oldest continent by admitting the waters of the Mediterranean to a series of the depressions, partially filled with fresh water, in the south of the French colony of Algeria. These lakes, locally named chotts, run dry at certain periods of the year. But a chain of them, the first of which is only separated from the Mediterranean by sandy downs, extends as far as Biskra, to the south of Constantine. The last of the chain being twenty-seven metres below the level of the sea, it is thought feasible, by cutting through the sand above the first chott, to admit the waters of the Mediterranean to this series of lakes, and thus form a salt-water lake at the southern extremity of the chain important enough to admit of the creation of seaports. "From these advanced posts,' says the author of the report on this scheme, "we should watch the nomadic tribes of the south. The numerous and

rich oases of the Souf and the Oued, now only nominally subject to us, would fall completely into our power. Our colonization would extend to the south of Constantine as surely as it is established on the Mediterranean coast."

BLASTING IN MINES BY ELECTRICITY.—The inventor of a very useful electric exploder, F. Abegg, engineer at Neu Bistritz, Bohemia, has continued to use almost exclusively, during a term of seven years, the electric current for firing blast holes, and he has at last succeeded in bringing his invention into a perfectly defined shape. Instead of galvanic, Mr. Abegg invariably uses frictional electricity for mines, which he produces with a small machine that is enclosed in a light case, and always ready for use. A very great advantage and saving by the use of electricity in blasting is derived from the possibility of igniting simultaneously a number of charges, when their spheres of active friability will join each other, and thus bring under violent vibration a much larger mass of rock than if the same charges were fired one after the other. These advantages are very conspicuous when driving or sinking in a hard rock. The system of Mr. Abegg is simply as follows. The electric exploder or machine is placed at a safe distance, say five fathoms above or by the side of the bore holes, and connected with a piece of cable which contains two insulated copper wires, the ends of which are b nt into eyes and protected against injury by being wrapped up with tarred hemp, so that only the eyes protrude. Into each is then hooked a piece of annealed iron wire, which should be at least 2.5 millimetres thick, and conducted to the blast hole. This is loaded with the usual charge of powder or dynamite, and at the same time Abegg's ignition rod is inserted. The latter consists of a round, straight rod of dry wood, tightly wrapped in oiled paper, with a groove on each side which contains a piece of conducting wire, ending at the top in an eye, and reaching at the bottom in the detonator or percussion cap, which is fastened to the end of the rod so that the electric current goes through one wire in it and returns by the other. In these eyes the further ends of the iron connecting wires are then hooked when the charge is ready for explosion. Where several holes are to be blasted simultaneously, it is only necessary to connect the two most distant holes with the machine, each by one wire only, and to complete the electric conduit between them by short pieces of wire which are hooked in the nearest eyes of the exploding wires. When the current is turned on it will run from the exploder through the cable and one iron wire to the first hole, pass from one to the other, and return from the last by the other iron connecting wire; and as the velocity of the current is so great that it is practically instantaneous, all detonating caps and blasting charges will explode exactly at the same time. Should the holes be very wet, it is only necessary to cover the igniting rods, besides oiled paper, with a thin layer of pitch, when they will never miss fire.

SAPPHIRES IN COLORADO.—The Denver, Col., *News*, of the 3d inst- says:

A miner who has been engaged some months past working in the bars along the Platte for five or six miles above Denver, had the good fortune to find several sapphires, which he saved, without knowing anything about their value. One day last week a stranger, who was prospecting along the river, was shown the stones, when he bought the largest one for two dollars. He brought it to town, and upon a test, it was pronounced a sapphire, and a very fine one. It was placed in the hands of I. Haberi, lapidary, to be cut. The rough stone weighed 19½ carats; and yesterday he delivered to the owner a beautifully cut gem therefrom, weighing fully 12 carats, and valued at $500. The miner was also in town yesterday, and became very much astonished upon learning the value of the pebble he had parted with for a two-dollar greenback. He left two more with Mr. Haberi, and proposes to enjoy, himself, some of the profits of their polishing. The gentleman who bought the first mentioned stone is experienced in such things, though a comparative stranger in this region. In the past week he has himself found within two miles of Denver an emerald, which he believes more valuable than the sapphire, and a very fine water agate which will produce a beautiful gem of strawberry color. He has sent the emerald east.

ACCORDING to competent authorities, the sulphur mines of Sicily will be exhausted in fifty or sixty years. There is only about 200 million cwt. to be extracted. The quantity taken out annually at present is about 2½ million cwt.; but allowing for the progress of industry, it may reach 3 or 4 millions. The Italian Government lately appointed M. Lorenzo Parodi to inquire into the present state and the future of this industry, and he has published an interesting report on the subject. The sulphur, it appears, is found in Sicily in two different forms; that of a deposit from volcanic emanations, named *solfatara*, and that of deep beds., in which it is associated with sedimentary rocks, and which are known as *solfaras*. The treatment of the ore is very primitive. It is simple fusion, in which the sulphur itself serves as fuel; and it is done in the open air, without any regard to the waste which results, and which is considerable. Thus the ore, which contains sulphur in the proportion of 15 to 40 per cent., yields generally only two-thirds, or, on the average, 14 per cent. The production of the mines has quadrupled in forty years, spite of the greatly increased consumption of pyrites (in which, it is known, the sulphur is combined with iron), and M. Parodi therefore thinks it inexpedient to abolish the export duties, which bring into the Government 2,000,000fr. per annum. in order to stimulate a production which will of itself go on increasing towards the date of exhaustion.

MR. CHARLES JORDAN, an ironfounder, at Newport, Monmouthshire, has taken out a patent for a novel method of preventing railway accidents. He proposes to make the up and down main lines without the usual switches, turnouts, and crossings, the lines being continuous from end to end, and to work such road by transferring a train or trains at stations, or where shunting is necessary, or at junctions with other railways, from the main line to the adjacent sliding, by lifting the train bodily from one line to the other by hydraulic apparatus.

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

No. LXIX.—SEPTEMBER, 1874.—Vol. XI.

A RECORD OF EXPERIMENTS, SHOWING THE CHARACTER AND POSITION OF NEUTRAL AXES, AS SEEN BY POLARIZED LIGHT.

By Louis Nickerson, C. E.

Transactions of the American Society of Civil Engineers.

Preliminary.—The experiments recorded in the following pages, were undertaken with a view to discover, whether the law of the "lamination of material in planes perpendicular to the direction of the pressure excited upon it," was a law incidental to a periodic* action of force, as pressure; or only consequent upon tangential stress, faults in the cohesion of material, or the running together of internal cells. The first of these was made by sending polarized light through plates of glass, compressed so as to be bi-refractive either in the character of beams or columns bearing weights.

As some exception may be taken to this apparently absurd means of obtaining the course of strains in materials used in construction, and because glass is itself a useless material for the sustaining of weights, it may be well that the experimenter's reasons for the proceeding should be given. The difference in effect between like action on two materials is not absolute, but only relative, therefore the effect of the action of force in glass must be similar to its effect upon other substances, excepting for amounts and confined qualities. One of these latter is transparency, but this becomes useful; and moreover, as the particular results which we wish to arrive at are derivable from certain general laws of the "doctrine of forces;" which must be precisely the same for all substances and only modified, not changed by any particular substance, and which the transparency of glass and its bi-refractive quality when strained enables us to watch with the eye of the body, in assistance to the eye of the mind; we may, in this partial case, completely ignore structural differences. So that, having become satisfied in regard to the general law, we may be better able to systematically admit the modifications. These modifications, indeed, would not appear to be very great. Glass, cast-iron and steel are all amorphous bodies, yet all composed of segregated crystals, and during the experiments a connection was established in the characteristic form of breakage; all as a general result appearing to yield in this form: when the fracture occurs in a beam between a supporting point and a point of pressure, and in this one when the fracture occurs immedi-

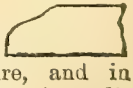
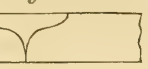


Fig. 1

* The word periodicy being used to express a re-occurring phenomenon without reference to the time occupied.

ately at a point of pressure: *Fig.* 2. it being readily noticed that the law of fracture



is the same in both cases; Fig. 2 being similar to Fig 1, with an opposite duplicature. Another and very important link of connection is believed by the writer to exist in the relative ratio of their respective resistances to tensile and compressive strains, as there is good reason to think that in this respect glass occupies a place between steel and cast-iron. These facts, however, become of less importance as we begin in the experiments to perceive the action of general laws, and to refer to their effects without regarding the vehicle which transmits them.

The form of apparatus used was the common one for experiments with polarized light, made without the microscope; namely, a bundle of glass plates—parts of window panes in this instance—6 by 8 inches. This was the polarizer, and one plate of heavy glass of the same size, blackened upon its back so as to reflect from only one surface was the analyzer. The first is set at an angle of 33° from the window through which the light is obtained, and the latter at an angle of 33° from the table upon which it is placed, or rather it is so placed that the rays of light reflected to it from the polarizer, come to the eye of the observer placed above at an angle of 57°. Between the polarizer and analyzer is held a small brass clamp used for compressing the object under examination. Looking into the analyzer, there is seen before compression, the clamp (a square frame of brass, with a thumb-screw moving from the top side towards the bottom) containing, in position, according to the experiment intended, a slip of glass, or a piece of glass tube or rod.

The glass appears clear and ordinary looking, because of the ordinary light which is present, but if our apparatus were so closed up on all sides as only to admit of the polarized rays, *it would appear black, for in a neutral or unstrained state, it is not permeable by those rays.* Yet even now, by close examination, we perceive a cloudiness.

Beams.—Supposing that our object is a beam, as *G* (see Plate), and we tighten the screw a little, immediately we obtain clear spaces with curved outlines at the top and bottom of the slip, while the darkness of the middle portion seems to increase. This dark space, in all its changes of form, marks by its outlines the neutral or unstrained sections of the beam. As it at first covered the unstrained beam, so it ever, by well-known optical laws, covers those portions of the beam remaining neutral or unstrained. Its increasing darkness, even, is only the effects of optical contrast; to pure polarized light it has always been black. Yet it does become more and more defined and distinct and narrower, as with the increasing pressure its outline becomes sharper. Soon, from the top and bottom of our beam, colored curves, each sharply distinct from the other, and having for their outlines the mathematical lines of strain, begin to make their appearance. As the pressure is more and more applied, they increase in number and brilliancy, moving always towards the neutral space. To a certain extent, there is a change of form, but the general curve is sustained until the period of fracture renders the image but a void of broken glass, the fractures of which may now be examined to obtain their position and character.

The images of *G* give a good idea of the results appearing in a beam, the ratio of whose depth to length is as 1 to 3.5, which rests upon two points of support, and which is pressed by a force partially local and partially distributed. The pictures opposite each other in the right and left-hand columns, are the positive and negative images of the same object in the same state.

The relative causes and properties of the positive and negative images, which together form each double picture, cannot easily be discussed until we have acquired, later in our experiments, a better knowledge of the character of the phenomena, after which, their great coöperative value will, doubtless, be admitted. They are, as arranged, images of the same state of the same object taken, first in one position, and then in another in the same plane, 45° distant, or by a revolution of the analyzer at each 90° distance. The words *positive* and *negative* are, of course, purely arbitrary, the negative image being the one occurring when the beam is horizontal and the column vertical.

The first matter which engaged attention and gave a definite course to the experiments, was the unsuspected and peculiar form and character of the neutral axis, and

systematic trials were shortly commenced to arrive at a full understanding of its status, under all circumstances of load and position. It will be remembered by engineers, that during the long, patient and able researches of Eaton Hodgkinson, F. R. S., published in 1842, he took the ground that the neutral axis was shifted by increasing the weights used, and, ultimately, that its position should be found at a line which would equalize the sum of the stretching and shortening forces, by a corresponding distribution of material above and below it. He fixed this line for cast-iron—at the period of rupture—one-seventh the depth of the beam from the top, because the resistance to compression of that material was seven times as much as the resistance to tension. He occasionally found rectangular beams, which broke, so that the broken edges exhibited a crushing force for one-seventh of their depth, while the tearing forces occupied the other six-sevenths, thus apparently corroborating his theory by an exact distribution of strains, in accordance with his previous experiments upon the compressive and tensile resistances of the material. Therefore, and most naturally, too, his whole argument makes it clear that he looked upon the neutral axis of the unloaded rectangular beam as a line at first coinciding with the longitudinal axis, but, which gradually rises towards the concave side at each accession of weight.

In 1855, Henry Barlow, F. R. S., made experiments upon cast-iron beams, purely to test this theory of Mr. Hodgkinson.* In the course of these experiments Mr. Barlow decides in direct contradiction to the views of Mr. Hodgkinson, that the neutral axis in a rectangular beam under all circumstances lays through the centre of gravity of the beam sections, and that there is a third element of strength consisting of the lateral adhesion of the fibres—"something like friction"—which increases with the curvature of deflection.

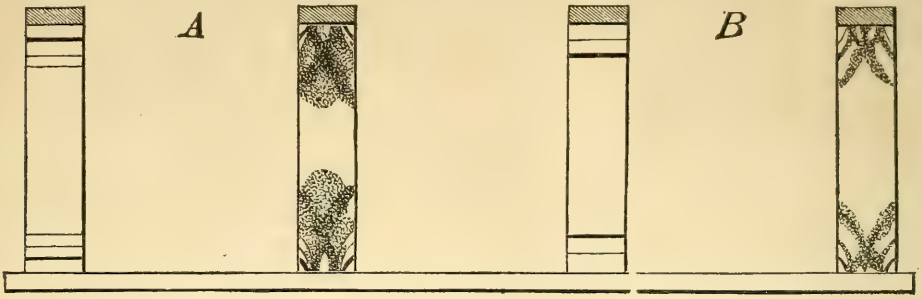
Both experimenters start from the same point, viz: that the transverse strength of a cast-iron beam is about 2.5 times as great as it would be to accord with experiments on its tensile and compressive strengths, and each records a different theory from the other in regard to the character and position of the neutral axis. This paper will show, that while both gentlemen were correct in the experiments made by them, these experiments were so diverse in character as to lead to two opposite theories by necessity, and by making a connection between the two sets of trials, also connect the observed phenomena and correct the theories. An attempt will be made to establish that the neutral axis is a flexible line, truly parallel to the top and bottom sides of the rectangular beam, and passing through the centres of gravity of its sections, only when the load is evenly distributed from end to end, or when the beam should be infinitely long; but that when there is a local pressure the neutral axis is more or less governed in its direction and form by the strain passing from the point of local pressure towards the points of support.

This mobile character of the neutral axis having been observed by the writer in his earlier trials, his first object when systematizing the further experiments was to obtain a law of direction, or rather to examine one already prevised. For this reason the negative image of column A was taken and recorded as evidently the simplest case that could be provided of direct compression. Then two slips of glass, C, were fastened in the press, so that when the pressure became heavy the two outside bottom corners should press against practically inflexible buttresses—the inside top corners press against each other—and the inside bottom corners and outside top corners of course be free. Thus there would be no tension in the beam, as a beam, and the compression could be governed by the screw until the coerced corners should be ground to powder. The image plainly represents two inclined columns like A each, or to speak more technically two "struts."

The simplest and most efficient way to conduct the experiment was obviously to make its different steps as closely consecutive as possible. The next object, there-

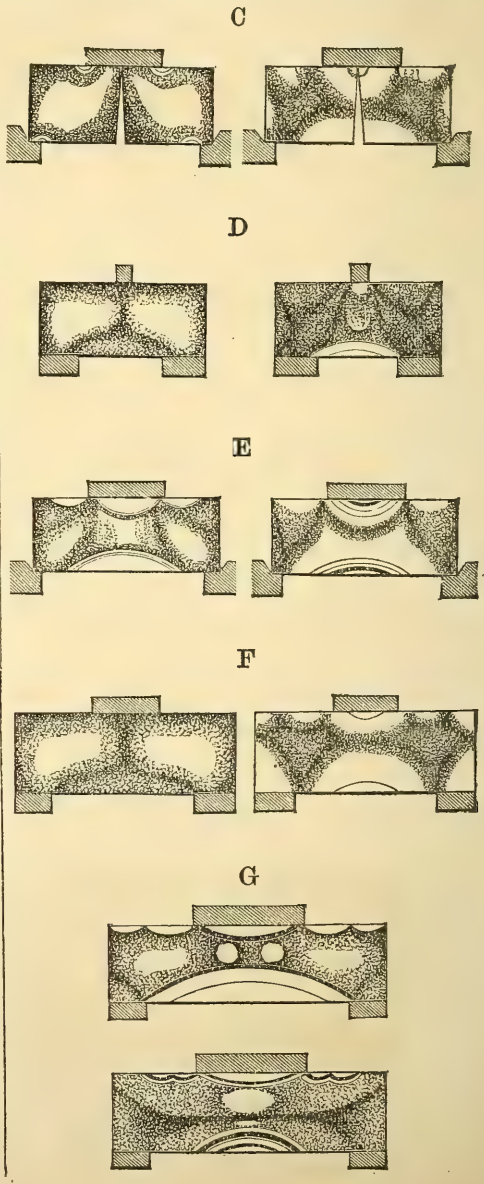
*He says: "It has long been known that under the existing theory of beams, which only recognizes two elements of strength, namely, the resistance to direct compression and extension, the strength of a bar of cast-iron, subjected to transverse strains, cannot be reconciled with the results obtained from experiments on direct tension, if the neutral axis is in the centre of the beam. The experiments made both on the tranverse and the direct tensile strength of the material have been so numerous and so carefully conducted as to admit of their accuracy, and it results from these either that the neutral axis must be at or above the top of the beam, or there must be some other cause for the strength exhibited by the beam when subjected to transverse pressure.

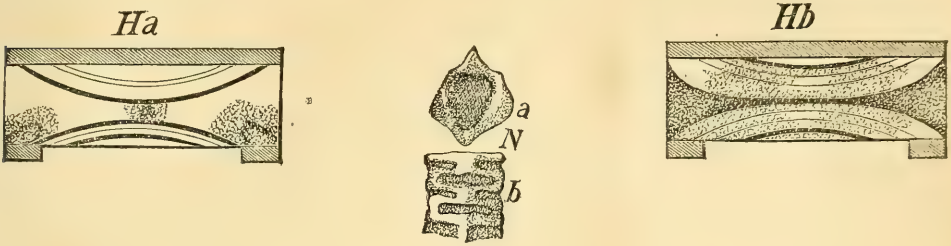
"In entering upon this question, it became necessary to establish clearly the position of the neutral axis, and the following experiments were commenced with that object, but they have led to others, which are also described herein, and which established the existence of a third, very important element of strength in beams."



fore, should be to attain a very small tensile strain with a great preponderance of compression. D, which was the next subject of trial, was a very short slip in proportion to its depth, with points of support very close together, so as to allow of but little flexurs, and pressed like the rest by the small leather guard of the screw. Passing across from the negative to the positive images for reasons to be hereafter given, a dark line surrounding a blue figure may be observed in *D*, as in the positive of *C*. Now, this blue figure is the complementary or positive appearance of the struts of negative *C* and *D*, and the dark surrounding line must, from the law mentioned in the first part of this paper, be neutral. In fact, the blue is in a state of semi-neutrality, shown by the small amount of the polarized light passed through it.

Confining the discussion to the neutral axis as it appears in the subsequent positive images, until experience shall have taught us the co-operative uses of both, let the beam which rests upon inclined but partially flexible supports be gradually lengthened in *E*. The blue is now less characteristically a strut, but the dark line still surrounds it. Only, however, on the side towards the middle of the beam is it plainly marked, and then not more so than in the new portion, which forms a curve extending from one corner of the "pressure block" to the other. The neutrality in this case, then, is in the narrow band running from one abutment in a curved line to the corner of the pressure block, from thence in a curve to the other corner of the same block, and from thence in a third curved line to the other abutment, and in two branches proceeding from the abutments toward the upper corners of the beam; the space between the first and third and the branches remaining, as it were semi-neutral. Looking backwards it will be perceived that the first and third lines, the branches and the

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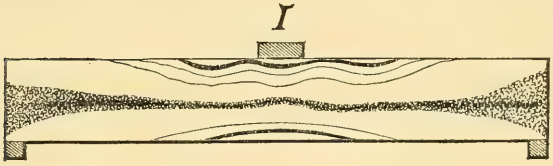
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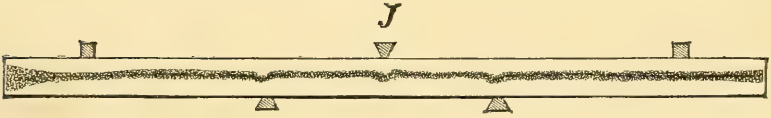
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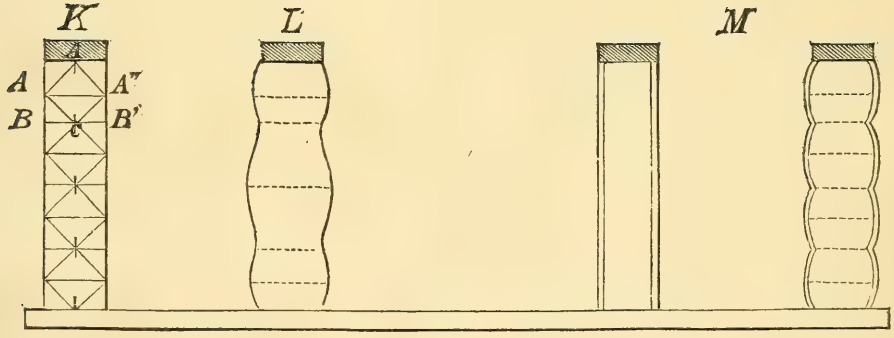
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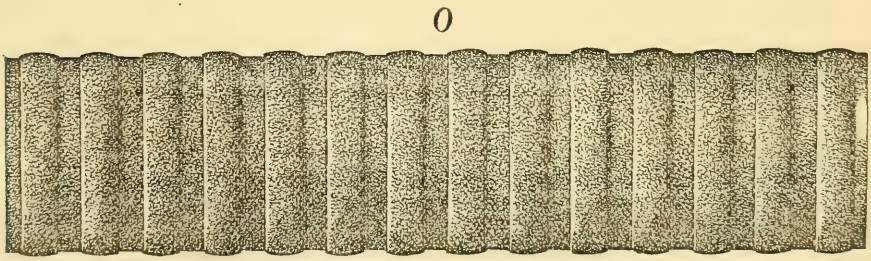
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$y = d\sqrt{\frac{R^2 - r^2}{2}}$

semi-neutral spaces result from the strut strains, formed by the direct compression from the pressure block towards the abutments, and we may begin to believe that the second line has been formed by the introduction of a distinct tensile strain along the lower part of the beam, creating with a horizontal compressive stress the bending moment which is just breaking in to complicate the strains. Simultaneously with this bending moment it will be perceived that colored curves appear upon the top and bottom of the beam. This beam, however, is far advanced towards the point of rupture.

F is a longer slip in proportion to its depth, but the local pressure still upon its centre. In this, the general neutral space is a broken curve or arch, from one abutment to another, only sending off cloudy branches, towards the upper corners of the beam, and the lower corners of the pressure block. This slip has, as yet, been little pressed, and the yellow color of the curves shows that they have but recently made their appearance. In *G* is shown the image of a beam upon the border of breakage, generally similar in character to *F*, but the beam being longer in proportion to its depth, the arch becomes much flattened; we still observe the running up of the neutral space towards the same points, and further notice that they inclose the colored curves in so doing, like the quiescent water which lies between opposite vortices.

H a, *H b*, is a beam with the load equally distributed. The "strut force" has disappeared from the top, and is only marked upon the beam, where, starting from the abutments, it becomes diffused about the centre, spreading, as might have been expected, when a local strain was changed to a general one, throughout the whole top of the beam. Undirected by a local pressure, it becomes undefined and cloudy, the neutral space belonging to the regular bending movement of the beam, detaching itself and becoming a horizontal line for the first time. The colored curves are regular and nearly equal on top and bottom, and with the exception of the "strut force" which appears in the negative at the abutments, and the complementary shading in the positive, there is no sign of local pressure. It may be noticed, too, how its colored curves are becoming more nearly similar in positive and negative images—how the colors are becoming more plainly complementary in the two images and how an umbra, which is a true neutral axis, surrounds the colored curves of the negative and connects them across the centre. Looking back, we may now perceive this neutral axis, in direction nearly perpendicular to the one in the positive image, has followed us up from the column to this point, and will beyond.

I is a long beam in the ratio of its depth, and we see clearly how its length, or rather its flexibility draws the neutral axis out into a nearly straight direction, parallel with the top and bottom edges; yet leaving perforce a slight upward tendency in the middle of its length due to the local force.

J is different in character from all the foregoing, and in attempt, represents a railroad bar pressed upon at one point, resting upon two cross ties, and prevented from rising by others, to which it is supposed to be spiked. Again the self-same laws prevail, the neutral space, in general horizontal, tends to bend itself toward each pressing point, and as in all the other images to brush out when free.

Those beams of Mr. Hodgkinson's by his own account, which plainly showed the neutral axis as being above the centre of gravity of the transverse sections of his beams, were *broken at the centre by a blow.* It was, therefore, as these drawings show, the local force and not the ratio of compressive and tensile resistances which governed its position. Mr. Barlow experimented with long beams, twice as long in proportion to the depth as any of those which appear here, and nearly 1.5 times as long as those mentioned by Mr. Hodgkinson in this connection. As the increase of the "bending movement," and the decrease of the "strut strain" keep pace with this lengthening of the beam in the ratio of its depth, he naturally found the neutral axis more nearly horizontal and less distorted than even in *I*. Beams of glass, with a ratio of 1 to 14, which is the proportion of those used by Mr. Barlow, show a very faint distortion from the horizontal and measuring as he did from points one foot distant from each other, this slight distortion might easily have escaped the scrutiny of his micrometer. Indeed it must be almost indefinite in beams having a ratio of more than 1 to 10.

May not it then be said of the neutrality as it appears by polarized light, that it is not a mere line in the mathematical sense of the word, but by reason of the cohesion

of material or other cause, is extended to a breadth, and can never become a true line until the tensile and compressive forces become in relation to the cohesion—infinite; or, in other words, that although the neutrality of "stress" is a mathematical line, yet as in material it must require a certain definite "stress" to produce a "strain," the initial "strain," namely, that sufficient to overcome cohesion must be at some distance from the mathematical line of neutrality. Beyond this it appears that its longitudinal diirection, like the directions of lines of strain, not an arbitrary one, but is resultant from the relative qualities and quantities of all the forces in the beam, its evident place in physics being precisely that of the still water between opposing eddies or vortices.*

Positive and Negative Images.—It will be noticed that as yet no cause has beeu discussed for the difference between the right and left-hand views in the plate—the positive and negative images. To understand these, it is necessary to know, generally, that polarized light differs from ordinary light, insomuch that instead of vibrating from a centre outward in all directions in the same transverse plane, the pulsations are confined to two directions which, when a completely polarized state is effected, are at right angles to each other. In this condition the pulsations in one direction are transmitted through certain substances, when the beam of light strikes them at particular angles, while the pulsations in the other are reflected, and *vice versa*. Secondly; if ordinary light, or either of these beams, are transmitted through a bi-refractive substance, there will be a division into two other beams at right angles to each other, and these falling upon an analyzing medium, properly arranged, will be either transmitted or reflected, according to the angle of their pulsations, so that the eye will be only able to discern the one reflected or the one transmitted. Thus the ordinary light coming through the window was polarized by falling upon the polarizer at an angle of 57°, one beam was transmitted, and, so far as we were concerned, wasted. The other reflected was made to pass through the object which, impervious to it in an unstrained state, became pervious and bi-refractive in a strained state, again dividing the one beam into two, at right angles to each other; the one of which is reflected to the eye from the surface of the analyzer, and the other transmitted through its face, but absorbed by the blackened back, until a revolution in part of the object changes the directions of pulsation and reverses the condition of the two rays.

When experiments were being made upon the first tubular bridges, it was found that a wave of "buckling" always followed an angle of 45°, from the top where the load was placed toward the bottom; even crossing the stiffners put in to retain this normal angle. This was similar in principle to what is here called a "strut strain." Evidently this would be impossible in equilibrium, unless there also existed a corresponding tensile strain at right angles. A resultant of these stresses in a beam would obviously be vertical. Again, it is known that the principal stress in an ordinary beam is the horizontal stress, composed of a compression in the top and a tension in the bottom, and that the resultant of these is parallel to them and is called generally the neutral axis. There are, therefore, two resultants at right angles to each other.

In the first section it was shown, that the true neutral axis of a beam was not necessarily the horizontal line, usually so called, but a line resultant from the actions of both the horizontal and strut stresses, which was derived from the fact that the neutral or unstrained part of the beam coincided with this form. In a beam loaded with a distributed load, or one which is very long in proportion to its depth, the strut stresses assume angles of 45°, as before shown in the case of the tubular bridges, become individually small in comparison with the horizontal or flange stresses, and the horizontal stresses govern the resultant almost entirely, but as the beam is shortened, so that the strut or web stresses between the load and abutments, obtain an ascendency over the flange stresses, then the strut stress interferes controllingly with the horizontal stress, and changes the direction of the resultant axis until in a column it becomes entirely vertical.

By a re-examination of the drawings it

* The neutral character of the dark bands is most plainly shown by working at an open window, where a large quantity of ordinary light is reflected from the polarizer. The neutral portions are pervious to ordinary light; and by this means a white speck set upon the polarizer may be made to pass across them, by a motion of the head, from one set of curves to the other, as a star passes across a clear belt of sky from cloud to cloud.

will appear that when the strut strains are in an ascendency over the horizontal strains, the negative images are by far the brightest, and although they afterward become duller—as the strut strains become relatively less—yet the preponderance of vertical stress is always evident in them. On the other hand, the instant a tensile stress was introduced, so as to oppose the compression or strut stress, and resolve the effect into horizontal or "flange" stress, the positive images became brighter, and continued so to grow *ceteris paribus* with the increase of the beam in length, and consequent relative increase of tensile and flange strains. Further, it should be remembered, that divers stresses may exist in the same piece of material, crossing each other, and probably being mutually neutralized at the crossing, but continuing on afterward as individual and intact as when first they met.

As the glass is pervious to polarized light, when strained, and impervious when unstrained, we can only regard the light parts as strained in proportion to their brightness, and the dark portions as unstrained or neutral; and as the strain is the cause of the bi-refraction, it follows that the latter must be governed by the laws which govern the former. Further, the resultant angles of the strains are rectangles, as are the angles of polarization, and as the strains change in character, so do the polar images change in correspondence. It follows, then, that the images are pictures of the strains.

But this may be examined in another manner. If all the light—except that which falls upon the polarizer—were dispensed with, the object seen by the eye without the intervention of the analyzer, would yield no appearance of color, but only white light. Now, all the stresses in a *beam*, when united, must be in equilibrium, hence the light which measures and was produced by them, should also be in equilibrium, or in other words, colorless when the two rays are united. From this is deduced that the positive and negative images are complementary in form and color.

Further, it may be fairly assumed, should these reasonings be correct, that if there is any one point in the object which is under no strain, whatsoever stresses be applied to the beam, that point must remain dark under all revolutions of the object or analyzer. Now, there is such a point in the centre of the beam, nearly in the middle of the primary neutral axis, and between the forks of the strut strains, and which, by laws already discussed, resolves itself into a space, and this dark space is always observable in the analyzer, forming a sort of nucleus, from which the changes from positive to negative and the reverse take place during the revolutions. It is obvious that this point marks the crossing of the resultant axes, the one formed by the "web" or strut strains, the other by the "flange" or horizontal strains, as before discussed.*

Colored Curves and Secondary Neutral Axes.—The appearance of the light around the neutral band is the first symptom of distortion in the positive image, but soon there appears upon the top and bottom edges faint segments of yellow. At the lower side this occupies a large portion of the distance between the points of support, but at the top it varies with the arrangement of the load, the chord to the segment having nearly the length of that part of the beam directly pressed by the load. If the load be uniformly distributed over the whole length of the beam, the segment is similar at top and bottom, but if this be local, say consisting of a block of hard sole leather as a guard to the screw, then the segment will have about the same length as the block, and two smaller segments, differing a little in form, will appear at the sides. Beyond these again bright curves appear, as though preparing for the formation of more colored segments; but the writer has never succeeded in bringing out more than three, with sufficient distinctness in the colors of the extra ones to be satisfied as to their character. It may not be amiss to remark here, that all the images and colors appearing were quite as distinct as the shades represented in the drawings.

As the pressure is increased, the yellow from both edges moves forward toward the neutral band, becoming soon a zone, and a segment of red succeeds. Both

* The writer will endeavor at a future time to present the concordance between the mechanical and optical phenomena, more in detail and with greater precision. For the present, relying mostly upon the success of the ultimate experiments to prove the law conceived to be true, he has preferred rather to suggest the line of argument than to closely follow it.

these continue to move forward with the increase until the red, too, becomes a zone and a segment of blue appears. This is the end of the first series, and we mark with interest that with the blue or between that and the red there came a dark mysterious line. Turning the screw continuously we force the yellow, red and blue to move forward, the blue becoming a zone, and bearing its dark line with it, which constantly grows darker, and yellow, red and blue again chase each other upon the field to form a second series. The second blue also has its dark line. So far I have found no glass to stand more pressure than this.

Let us now remember Mr. Barlow's words: "But they have led to others (experiments) which are also described herein, and which establish the existence of a third and very important element of strength in beams."

In loading a beam, it is probable that the pressing force first seeks to connect itself with, or as it were feels for the points of support; afterward the bending action commences. Now, suppose the load to be very small at first, and gradually to increase, there must be a time, for the new resistance can only exist, according to Mr. Barlow's experiments, after the beam is bent somewhat—when this resistance is only just equal to that portion of the moment of the compressive force (we are discussing, for simplicity, the top part of the beam), which is directly opposed to it, and which may therefore be called the bending stress. Taking the vertical section through the middle of the beam for the discussion, we may fairly suppose that this occurs just when the dark line between the first blue and red comes upon the glass. Mr. Barlow has shown that the new resistance or resistances increase as the beam is bent, but as we know that by the increase of load the beam is still further bent, we derive that the bending force increases faster. Therefore, if at first the bending resistance, multiplied by its minimum statical arm, was equal to the bending stress, multiplied by the distance from the neutral axis to the top of the beam as its maximum statical arm, which at equilibrium it must have been, it must at last be equal to the increased bending stress, multiplied by a shorter arm, itself being now multiplied by an increased length of arm, whose axis is at the top of the beam. The line of equal moment then between these two forces must have moved down in the interim nearer to the primary neutral axis, and must continue to move downwards toward this axis as the load is increased. This is exactly the action of the dark line in the blue, and its appearance, to one frequently engaged in examinations by polarized light, is that of a line of equal antagonistic forces—in other words, a neutral line.

In a first examination of this matter there seems to be something anomalous in the fact of a neutral axis existing amid distorting forces, of a line in the top part of a beam which is neutral, yet growing shorter, or in the bottom part and retain its neutrality while increasing in length. But it is not so; for if we should load a beam to bending, and then without changing the relative status of its flange strains, compress or stretch it bodily in length, we should have precisely the same phenomenon—a line which is a neutral line between two forces—yet increasing or decreasing in length by the operation of other forces acting independently of the first. There might be a modification of form besides the change in length, but there could be no cause for annihilation.

Further notice of the movement of this secondary neutral line (if we may call it so), toward the primary neutral line suggests that should the two come together, then, according to our former reasoning, the bending stress, multiplied by its smallest statical arm, would have become just equal to the bending resistance, multiplied by its longest possible statical arm (from the top of the beam to the neutral axis), and that any additional increase of the bending stress, however small, would bend the beam infinitely, because totally unopposed; or in other words, the beam would break. This reasoning was curiously confirmed in the following manner: while watching the consecutive phenomena occurring in several slips, set one upon another, thus forming a laminated beam, with a small hand microscope, all the slips, save one, suddenly broke. For some reason, perhaps from the elasticity of the broken glass, or perhaps the screw which had been shortened by the reaction of all the slips, began to recover its length when only resisted by one, the secondary axis continued to move forward, so that the observer, not having the screw to manage, could watch its movements at leisure. As it neared the pri-

mary axis, its curve began to take the form of a bow, the two quarters passing the middle in the direction of motion, and when very close, two loops were prominently advanced, first one and then the other. As the first touched the primary axis, a sharp "click" was heard, and fine fragments of glass flew like hail from the sudden rupture, which followed just at *that point*. Immediately the second loop touched, with precisely the same phenomena, when the vision was gone and only fragments of glass remained. It is to be regretted that the flying of the glass particles made it impossible to watch the movements of the secondary axis in the lower part of the beam, or either of the dark lines in the second blue, but closer preparation at another time, when the phenomena is looked for, may lead to interesting results.

Columns.—The column appeared to us at first as incidental, taking a subordinate place in discussing the general laws of a compressed beam. We shall now see that its own phenomena are well worthy of deep study—that it resists pressure by strange geometric laws, and marshals its forces to oppose coercion from a vast depth of mathematical resource.

Although with glass, probably on account of its hardness in relation to the screw, it seemed impossible, before breakage, to obtain more than from 3 to 6 rings at either end, yet when a softer material, such as copal, was used, the column was wreathed in colored bands from top to bottom. Observe the dark band between the blue and red. Its position is invariable whenever these two colors come together, and from the first my suspicions were decided that it marked either an unstrained path in the column or a division of equal antagonistic forces. In fact, we must not regard the bands as horizontal strata, but rather as sections of oblique planes which follow the directions of stress. (See diametric sections *A* and *B*, which are the negative and positive images of the same object.)

It was with a view of assuring myself of the truth of these suspicions, that I one day asked permission to search through the store-room of the Illinois & St. Louis Bridge Company for corroborative phenomena. In this room were many objects, crippled and otherwise, which had been tested in the testing machine belonging to that company, and I was in hopes of finding in changes of form some assimilation to the arrangement of colors in the glass columns, and especially something to corroborate the neutral character of the dark line, as already provided. There was no want of testimony in any piece of the existence of a wave action in the pressure, but in the solid bars this was confined to a cone like flattening (upsetting) at either end, and a determined "bulging" in the middle for those compressed, which was reversed in those subjected to tension. It was common to steel, iron, wood and cement cylinders (see *L*). Attention, however, was soon concentrated upon the tubes, all of steel, which plainly exhibited a periodic wave apparently at regular distances from end to end. Not being prepared at the time to measure them carefully they were left for a future occasion.

Still further to test the matter upon material, which would yield form instead of color to the forces brought to bear upon it, arrangements were made by me for a change of experiment. Definite trials were made upon brass tubes .45 inches outside diameter, .35 inches inside diameter, and a length necessarily confined to about 1.5 inches by the small clamp used. These were compressed longitudinally by a screw until the form assumed was permanent. *M* gives an idea of their original and assumed appearance. These trials have been carried through some 12 or 15 tubes and the results subjected to measurment, the store-room of the Bridge Company was again visited, and a scale used to measure, as correctly as possible, the distance between the waves on the steel tubes. Then, with very little labor, the results were tabulated, and with not much more (since either the outside or inside diameter, or the radius of gyration, were almost obviously the base, and some oblique line proceeding from the axis of the tube outwards, as certainly the hypothenuse of a triangle of pressure) the following empyric expression was derived, which, so far as I can discover, will locate any wave in relation to another, the material of the tube being of course equally resistant from end to end. Measuring from ventral to ventral, we have when $x =$ distance, $R =$ outside radius, $r =$ inside radius, $a =$ constant quantity varying with the material alone and dependent upon the angle at which it most easily yields.

$$x = a\frac{\sqrt{R^2+r^2}}{2}.$$

This formula seems for brass tubes to become, as nearly as could be discovered,

$$x = \tfrac{5}{6}\frac{\sqrt{R^2+r^2}}{2},$$

and for steel tubes,

$$x = \tfrac{2}{3}\frac{\sqrt{R^2+r^2}}{2},$$

a being equal to unity. The steel tubes measured, varied from 1.5 to 2 and 5 inches in outside diameter, the waves on the only one of the latter present being perceptible, but faint except at the ends, from 1 to 42 inches in length, and from .05 to .25 inches in thickness of wall. They were 9 in number.

It became now necessary to show some cause for these phenomenæ and to bring their relations with the colored rings in the glass column, and especially with the dark line between the blue and red, into closer connection. With this idea a theory already prevised in part from the colored rings was taken up, with what appears to the writer a successful issue, as follows.

We learn from Rankine's "Civil Engineering and Applied Mechanics," that "no tangential stress can exist as a simple stress, but must be accompanied by another stress upon another plane, and that these two stresses have a resultant, which becomes a maximum when they are equal, departing from each at an angle of 45°."

Let us then consider the condition of a solid or hollow column, pressed evenly over the top by a great load, and resting upon a flat surface at the bottom. Evidently the weight must exert a tangential stress upon the walls of the hollow column, or the edges of the ultimate particles of a solid one, and as the longitudinal section of the column is rectangular, we may look for the accompanying stress to be at right angles to it. Let us for convenience consider these stresses to be equal, their resultant will have a direction between them and 45° distant, and if K represent the column, $A\,A'$ and $A\,A''$ will represent the resultants of the stresses. But these resultants act to push the material outwards at A' and A'', and as their action is, therefore, tangential or distorting, there results from our first law, and directly from this effect, two other "accompanying" stresses, C, A' and C, A'', which tend to draw the material atoms from C towards A' and A''. Now, where these stresses interfere at $A'\,A''$, they mutually neutralize each the vertical component of the other, so that there only remains at $A'\,A''$ horizontal forces, and where they interfere at C, they mutually neutralize, each the horizontal component of the other, so that there only remains at C the vertical component, equal to the weight at A, with which we commenced this discussion, and the plane B, B', is precisely in like condition as regards stress to the plane at A. It follows as a corollary that like conditions below B, B', will produce like results to those at A, and B, B', and so on for any number of equal divisions or periods, and it also follows that such planes as A and B, B', etc., are unstrained by horizontal forces, and should, therefore, appear dark in the positive image, and that such planes as $A'\,A''$, etc., are unstrained by the vertical forces, and should, therefore, be dark in the negative image, which, in the bi-refractive glass columns, under polarized light, we find to be true, while in the metal tubes compressed we find a concording form.

L shows the form of the wave assumed by thin brass tubes—probably any thin tube—which has for its periods the same formula as the thicker ones, but differs in the vertical fold, and the consequent interlaced triangular section. It is probable that the vertical fold does not occur from any definite change, but only from a modification of our law, and may rather be regarded as a buttress, thrown out by tubes of a certain thinness, to resist transverse bending, and from thence propagated, by the natural pulling of the force of its creation, upon straight lines, and located by the well known properties of the equilateral triangle as a perfect figure of equilibrium. Its position in the succeeding period midway between those formed above it, so that one triangle interlaces with and bisects the other, may also be accounted for by the fact that the middle of the side of the triangle is its weakest point, and the new buttresses are thrown out there in consequence of greater yielding at that place.

Remarks on Attendant Phenomenæ.—It was apparent during the course of these experiments on columns that each piece of material was mechanically polar, or, in other words, had a favorite end. This was shown in glass and brass by the end against which the screw-plate worked,

yielding first. In the thick tubes, and in transparent columns, this was followed by the other end, and in the same tubes, and in softer transparent material than glass, by the intermediate ventral points. Of course, after a certain yielding in glass columns, the balance of compression was against the brass screws, which then yielded more in this direction than the glass, the glass column ultimately giving way by splitting down perpendicularly, as all vitreous substances naturally do, except a transverse crushing where the rings had appeared, making a nearly cubical fracture. In thin tubes the waves formed from the screw or active end towards the other end consecutively.

When, as frequently occurred, the tubes were not of exact length to make a regular succession of equal waves, then the difference was invariably made upon the base or passive end by a half wave longer or shorter than the normal half wave shown at each end in the drawings. In only one case was an abnormal wave noticed, this in a brass tube with an evident soft place in the material, which divided into five waves in the usual space for four, one wave coming within the soft place.

In the proposition it will be noticed that the lines $A\ A'$, $A\ A''$, $C\ A'$ and $C\ A''$ are straight. This was only the natural result of an attempt to investigate forces proceeding from one point to another. Subsequent experiments, which have not been as yet sufficiently wrought to publish, lead me to regard these as curved lines, and to consider the figure $A\ A'$, $C\ A''$ as approaching an ellipse corresponding to the rhombus shown. The figures in the lower divisions would then, of course, suffer the same change from the same law.

I have thought if large, hollow columns yie ded under the same law, and it should appear as apparent from the proposition and from other facts, that the law governs before the limit of elasticity was reached. then by reinforcing columns by bands shrunk on at the places pointed out by formulæ, we might greatly strengthen them at a small expense for additional material in the shape of rings (See O).

In conclusion, it seems to me, subject to higher decision, that the law of the periodicity of force in pressures, and probably in tension, has been fully proved in this paper, which will assist in accounting for the effects of re-occurrent applications of force and for the law of lamination under pressure, in planes perpendicular to the direction of pressure.

Mr. Charles Macdonald.—The experiments upon which formulæ in common use, for the proportion and strength of beams, are based, were made upon cubes of the materials tested; and it is found that the constants derived are inapplicable to ordinary cases in practice. It is known that a beam, loaded so that its outer fibres by formula should be under maximum strain, will stand a greater load. The constants employed in calculating the strength of a beam should be determined from experiments upon a similar beam of the same material, and not those given for direct tension and compression.

Mr. Alfred P. Boller.—A recent comparison of various standard formulæ for the strength of beams, made by taking a given beam and calculating, with each formula, its safe load, gave as follows:—two, 25 tons; one, 30 tons; and one 37 tons. The last was from Mr. Baker's formula, in which he has introduced the resistance due to flexion. The beam taken was 3 by 6 inches, and 5 feet long. Engineers should know more of the strength of materials. The formulæ used involve the application of constants ranging variously from maximum to minimum strength. These often differ widely, and, therefore, give uncertain results.

Prof. De Volson Wood.—The point of greatest interest to me in the paper read, is whether the neutral axis is a line, or a space as water in an eddy. In regard to the neutral axis and strength of beams, as determined by ordinary rules, the fact is, if we assume in a bent beam that the extensions and compressions are proportional to the distance of the elements from the neutral axis, and take the modulus of tenacity or of crushing, as the case may be, for the modulus of rupture of the beam, a beam proportioned in accordance therewith will have an excess of strength. To illustrate this, take the case of cast-iron, which is the best example in practice—the mean tensile strength (T) of cast-iron is 16,000 pounds, and the mean crushing strength (C) is 100,000 pounds, or, for convenience, six times as great as the other—96,000 pounds. If the beam is rectangular, supported at its ends and loaded in the middle, we have the well known formula:—

$$\tfrac{1}{4}\ P\ l = \tfrac{1}{6}\ R\ b\ d^{\,2}$$

in which P is the weight, l the length of the beam, b its breadth, d its depth, and R the modulus of rupture. According to this theory, the value of R should be 16,000 pounds, but according to experiments it is found that the mean value of R for cast-iron rectangular beams is about 36,000 pounds Former writers do not explain this discrepancy, but simply admit a defect in the theory, and pass it over by saying that a proper co-efficient of safety will make the formula a safe one. Barlow detected a new element of strength, which he called "resistance to flexure," a term which is unfortunate, as all the forces in a beam which resist bending, are resistences to flexure; "longitudinal shearing resistance" is a beter term, and one now used. This force is the resistance of the fibres to being drawn over each other. If there were no such resistance the fibres would retain their original length. To illustrate, suppose that several very thin but perfectly smooth boards of equal lengths were placed above each other, and supported at the ends. If now the pile of boards is bent, all the boards will retain their original length, and the ends will set past each other, as shown in Fig. 3, but the general range of the ends will be parallel to each other. If we suppose that there is friction between the surfaces of the successive boards, the upper ones will necessarily be shortened, and the lower ones elongated. In a beam, the consecutive elements are united by cohesion, and Barlow found by a critical examination of those of cast and wrought-iron, that the transverse sections remained normal to the neutral axis during flexure, and in this case the ends will not be parallel, as seen in Fig. 4. This being so, and bearing in mind the analogy between this case and that of the thin boards, we see that besides the forces which produce direct elongation and compression, there is a force between the consecutive elements somewhat analogous to friction:—this is longitudinal shearing resistance. Barlow found the laws which govern this resistance atthe point of rupture, and modified the formulæaccordingly. The mode of his investigation and his results are fully described in the "Civil Engineer and Architects Journal," Vols. XIX and XXI. I consider them the most weighty and valuable sets of experiments that have ever been made upon beams, so far as theory is concerned.

Fig. 3.

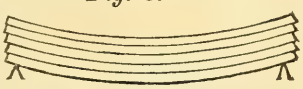
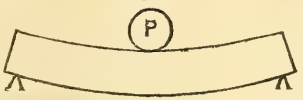


Fig. 4.



It is evident, the ordinary law that the strains vary as their distance from the neutral axis can not apply to ⊥ sections, for to secure such action there must be at least a continuity between all the elements of the flange and those at the natural axis. Barlow made his formulæ applicable to this case, but it is equally evident that they cannot be rigidly correct. In all flange sections there is a peculiar combination of the strains about the angles where the flanges join the web, and it seems impossible to assign the laws which govern them.

Prof. Norton, of Yale College, determined from direct experiment, the fact of a transverse shearing resistance in beams, and also the laws which govern it for rectangular beams. His article was published in the "Journal of Arts and Science" and in "Van Nostrand's Eclectic Engineering Magazine." I had detected the same analytically. If transverse elasticity only existed in a beam it would be deflected. To show this by a figure,—suppose that short portions of the beam were perfectly non-elastic, and that between these were elastic sections. Then will a beam which is supported at its ends, and loaded at the middle be deflected, as in Fig. 5. If the beam has a continuous tranverse elasticity, it becomes evident that the deflection will be as shown in Fig. 6. The deflection due to this cause is additional to that due to Navier's theory, while long itudinal elastic shearing resistance will diminish it.

Fig. 5.

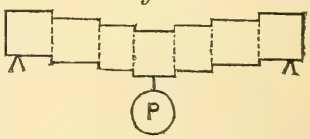


Fig. 6.

It is worthy of note that the strength of beams, as determined from Barlow's new formulæ and constants, agrees remarkably well with the actual strength for all the forms which he used. It is hardly to be expected that a simple law, or laws, can be given which will be applicable to all the forms of beams now used in practice. The constants which are determined from solid rectangular beams will doubtless apply

practically to solid beams of all dimensions, but not to other forms. For instance, if solid cast-iron beams give R=36,000 pounds, it will not be safe to use this value for hollow beams, or ⌶ beams. For such beams T=16,000 pounds is safe, but may give an excess of strength.

Mr. Boller.—It is best to make a beam proportioned similar to those to be used. Break it and deduce therefrom a constant. The formulæ for ⌶ beams are safer for thin than thick webs—say ¼-inch web and 4-inch flange.

Prof. Wood.—The experiments of Baron Von Weber, "Engineering," 1870, showed that the web had never been made too thin. Where the flange and web are joined there should be a large curve.

Mr. Macdonald.—In T. C. Clarke's description of the Quincy Bridge, there is a statement that 12-inch ⌶ floor beams, 15½ feet long, suspended in pairs from panel points about 12 feet apart, and carrying a single track of 4 feet 8½ inches gauge, scarcely deflected under a maximum engine load, which caused a strain upon the outer fibres at least equal to 14,000 pounds per square inch, according to formulæ in general use.

Prof. Wood.—We should not proportion structures in reference to the ultimate strength of the parts, but in reference to their elastic limits. The elasticity of the material should not be damaged. Some irons which are very tenacious have a low limit of elasticity, while others, and especially certain grades of steel, seem to preserve their elasticity for a strain nearly equal to half their tensible strength. Capt. Eads, in the construction of the St. Louis bridge, insists upon preserving the elasticity of the steel, and very careful experiments are made to determine its elastic limit.

Col. W. E. Merrill.—I regret I cannot give this as thorough an examination as I could wish. It opens a field for investigation that promises the most useful results in a matter of vital interest to Engineers and Architects, and in fact to every one; the laws of the action of strains on materials used in construction, and the proper method of meeting and sustaining them with assured safety. Being quite unfamiliar with the use and laws of polarized light, I do not feel competent to discuss the very interesting results obtained, but the method chosen, and the means pursued, seem most admirable. The plan of using glass to find out the laws of steel and iron, reminds me of the practice of physicians in ancient times of determining the laws of the human boby by experiments upon inferior animals. The limitations of sense having apparently put an insuperable barrier to the examination of the interior of opaque bodies under strains, the method by analogy seems the sole one that is open to us, aided of course by what we can see on the surface, and detect after fracture.

I have often thought it desirable to be able to see exactly how the strains in the different members of a truss bridge were working during different positions of the moving load. The method of Mr. Nickerson seems to offer that long-needed means. Further experiments will, probably, enable the experimenters to decide with fair accuracy upon the magnitude of an unknown strain on a glass column, by comparison with the observed effects of a known strain upon a similar column. I would suggest that a model of a Howe truss bridge be made with glass members and metallic joints, so constructed as to permit the ready insertion or removal of glass columns, acting as struts, ties, and chord segments. I believe that such a model can be made and so adjusted that broken parts can easily be replaced. If then the method with polarized light be used, valuable information about points now somewhat obscure could be obtained so as to command universal credence.

The proposed strengthening of tubes by external rings, at regular intervals, is a very curious result of the experiments, and if confirmed by practice, will be a valuable discovery. The whole discussion illustrates most admirably the inter-dependence of all branches of physical science, and the absurdity of considering any discovery useless, no matter how far it is apparently removed from a possibility of practical application in the useful arts. Hitherto the polarization of light has seemed a curious and occult phenomenon, of no particular utility, and only interesting to the man of abstract science, and here it suddenly springs up as a trustworthy means of unveiling the secrets of nature, and promises as great a future of discovery as the spectroscope.

Hon. William J. McAlpine.—As a practical question, the Civil Engineer has almost never to deal with glass as a material of strength, but it must be evident to all,

that it will be affected in the same way as any other material of similar construction, and hence that the effects of strains upon glass will be similar to those upon cast iron. At least the experiments made with such apparent care would be of great value in determining the law upon the subject.

It is a singular characteristic of this age that every discovery in science is made applicable to the service of our profession. Five years ago Prof. Airey (the Astronomer Royal) gave a paper on a new system of calculating the strains on each member of a truss, by a model in steel, which he had exactly duplicated. When the model bridge was loaded in all of the various ways, each member was struck, and the corresponding duplicate was loaded gradually until the two were in accord. The load on the duplicate indicated the strain on the corresponding member of the truss in position and under its load or strain. There we had *sound* to determine a most important engineering question; and now we have *light* in one of its forms of action.

Gen. J. G. Barnard.—I have been unable to give the matters presented by Mr. Nickerson the study required for a full appreciation. I would remark, however, that the peculiar circumstances under which the experiments for the neutral line or axis are made, are really foreign to the subject of the position of that axis as it is presented to the engineer in connection with the theory of the strength and stress of beams. That theory and the formulæ deduced, are like nearly all our mechanical theories of the properties of matter based on somewhat rude assumptions. Moreover, the formulæ for "beams" really suppose the length to very great, compared with the depth—practically infinite. No one supposes that, in pieces so short as the glass specimens experimented upon, the "strains," "stresses" and "strength" would be represented by the usual formulæ for "beams." That theory ignores all "strains," in the technical sense of the term, except those due to the elongation of fibre on one side of the neutral axis, and its forced contraction on the other. It is far from being a true exposition of the phenomena which are developed by the bending of a beam. The truth is limited by the imperfection of elasticity, and by any amount of deflection given to the beam beyond a very limited and exceedingly small amount; for tangential (or shearing) strains are disregarded.

The experiments upon pieces so short as those used by Mr. Nickerson develop phenomena which scarcely belong to the theory of beams, or to the position of the "neutral axis" in the usual acceptation of the term. I do not, in saying this, depreciate the value of experiments of that kind. They are directly applicable to the illustration of the strains produced in columns—and in all pieces subject to similar stresses I would remark, too, that glass, to the extent to which it is capable of receiving change of form without rupture, is almost perfectly elastic. Iron is far from being so, at least beyond the narrow limit to which it may be distorted without "set."

I am not familiar with the investigations of Mr. Barlow, but if the stress in a bent cast-iron beam be a "uniformly varying" one, he must prove, I think, that the co-efficient of elasticity is constant for all degrees of extension. That co-efficient for wrought iron varies in a table given by Morin (taken from Hodgkinson) to an extraordinary degree; being for extreme extensions, only about $\frac{1}{22}$ of its value for very small extensions; though within limits of practical strains—say to about 18,000 pounds per square inch, the variation is small, say $\frac{10}{22}$ of its maximum. For cast-iron the co-efficient for extension exhibits some variation also, in practical limits of stress, that is within limits of safety. For compression, both of cast and wrought iron, the co-efficient is (within practical limits say up to 15,000 or 18,000 pounds per square inch) more nearly constant in both materials.

In the experiments* made by me on the strain and rupture of beams of forged and cast-iron (of dimensions never before experimented upon, I believe), the co-efficient of elasticity as deduced, from the assumption of a "uniform varying stress" in the cross section, and a central neutral axis, varies in one of the forged specimens from 1,482,000 to 9,558,600 pounds per square inch—the smaller co-efficient corresponding to the extraordinary extension of fibre of .0463 and a "tensile strength" of 68,450 pounds per square inch—calculated from the amount of deflection of the beam)—and this extraordinary extension and this high tensile strength is exhibited in the iron of a *heavy forging*—*i.e.* in a forged beam, 15 by 12 inches in rectangular section. On the other hand, a cast-iron beam of the same dimensions, rupturing under a force

* Transactions XIV.

of 276 tons with a flexure of $\frac{3}{8}$-inch (the supports being 77 inches apart), exhibited a (calculated) extension of fibre of .00573* and a co-efficient of elasticity of about 40,000,000 pounds per square inch; and at the lesser flexure of $\frac{1}{4}$ inch (the only other observed), the co-efficient was about the same.

The variation of the co-efficient of elasticity under different degrees of extension, seems to me to be proof positive that in a bent beam there cannot be "uniformly varying stress" for while the extension of fibre varies, as it must do, nearly uniformly from the neutral axis to the exterior, the co-efficient of elasticity, the constancy of which is essential to a corresponding uniformly varying stress, is, in wrought iron, far from being constant. The co-efficients for cast-iron vary much less than for wrought iron—and indeed, my experiment just cited, with a cast-iron beam while developing an "extension" of .00573, which is nearly four times as great as the maximum extension in the table of Hodgkinson's results, given by Morin† .00155, indicate at that extreme extension the same co-efficient nearly, as for the less extension of .00382. Hodgkinson (as quoted by Morin) gives almost identical co-efficients of elasticity for cast-iron for compression as for extension: hence it may be presumed that the same is the case in the cast-iron beam ruptured by me.

There is, therefore, in this important experiment—the largest beam, I believe, ever ruptured experimentally—some confirmation that, for cast-iron Barlow's theory is true, viz.: that the stress in the cross section *is* a uniformly varying one, and that the neutral axis "transverses the centre of gravity." Yet from this experiment we deduce a discrepancy between the "modulus of rupture" and the "tensile strength" of the iron, even greater than for the case of the wrought iron beam in which enormous variation in the co-efficient of elasticity is clearly shown. The modulus of rupture for the 12 by 15 inches cast-iron beams would be, in one case, nearly double—in the other about 1.5 times the "tensile strength."

Mr. Barlow is probably right in the opinion (as stated by Rankine), "that the curvature of the layers of the beam produces a peculiar kind of resistance to bending, distinct from that which arises rom direct elasticity." It is evident that the theory of a horizontal neutral axis, however convenient, cannot be a true representation of the phenomena of the resistances developed in bending a beam.

Let us suppose the solid rectangular beam *A, B, C, D*, Fig. 7, resting upon supports at extremities to be bent to a *given deflection* by a force *P* applied at the middle. The neutral axis along the middle (according to theory) would be the line *m n*, and moreover the entire horizontal section *m n*, is in a rectangular section (or other symmetrical section above and below this plane), reckoned as neutral. But it is evident that it cannot be strictly so — evident that to stresses transmitted across it the three-fourth's computed resistance to flexure is due. For, let the beam be split along the section now, it will become two beams, of which the contiguous surfaces *m n* will slide over each other, and, the flexure being maintained the same, the two halves will appear as in Fig. 8, and the force to produce the flexure will be but $\frac{P}{4}$. There cannot, then, be a neutral line or plane along *m n*, and it may be doubted whether there can be really neutral lines or planes *anywhere* in a bent beam.

Fig. 7.

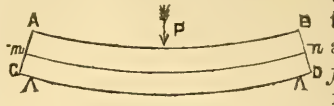
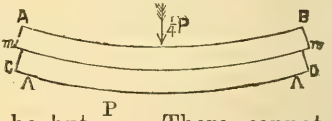


Fig. 8.



Researches with a perfectly elastic material, as glass, and one, too, which can be made to reveal to the eye indications of its internal strains, cannot but throw light upon one of the most difficult problems in mechanics, viz.: the internal strains of solids subjected to the action of external or internal forces. The general problem can be stated mathematically; but the analytical solution, except for a few simple cases, defies mathematicians. That portion of Mr. Nickerson's researches concerning the strains in hollow columns is very interesting, and I am inclined to regard his views on the "periodic" character of the strain, and upon the means of counteracting it, as well founded.

Mr. E. A. Fuertes.—Some time ago I noticed a flare or wing-like streak of

* On page 5 of the paper referred to, there are errors in the printing of the figures for the "extension of fibre." They should be .00382 and .00573.

† "Resistance des Materiaux." Morin.—1855.

light when examining the image of a star through my equatorial telescope. Fearful of some accident having taken place and impaired the object glass, and not being willing to remove it from its cell, I held in front of it a spirit lamp, on the wick of which I had poured some common salt. I at once observed the formation of Newton's rings on the lenses, but near the edge of the cell holding the lenses, the rings, instead of being concentric were scalloped, or bent inward toward their centre. Remembering experiments made by Pasteur, upon the pressure of mercury over a thin glass surface, I further examined the cell, and found that the disturbance of Newton's rings occurred near one of the screws which held the cell on the barrel of the telescope. I loosened the screw, and, to my great and natural delight, the interference suddenly disappeared. It was then evident that the cell had contracted through cold since the time at which it was screwed in the telescope, and that the pressure produced by this contraction caused the imperfection of the image, the location and extent of which was revealed by the soda light.

Gen. T. G. Ellis.—Several years ago I gave much thought to the subject of strains in beams, and regretted that those who had given their attention to experimenting, had pursued their investigations in so unscientific a manner. Mr. Nickerson's examinations are a step in the right direction, although I do not see that he has developed much more than has heretofore been done by Wertheim of Paris, who invented an instrument for the determination of strains and pressures by the colors of polarized light. Prof. Tyndall has also done the same. I sincerely hope that Mr. Nickerson will pursue the matter further. What we want to know is the elastic resistance to tension and compression in any one substance, as glass, and the effect of a weight upon a beam of the same substance. Then, knowing by experiment the elastic resistance in both directions of other substances, we might reason with some hope of success upon the position of the neutral axis of beams of different substances In my opinion a great error of writers on the strength of beams is, in assuming that equal strains will elongate and compress the same substance to an equal amount, thereby making the neutral axis of the horizontal strains in the middle of a rectangular beam; also in assuming that the elastic resistances are proportional to the ultimate resistances of the material.

One part of Mr. Nickerson's experiments that I do not clearly understand, is, how polarized light can show a neutral axis in a glass beam supported at the ends with a weight in the middle. It seems to me that it should show only a neutral *point* in the middle of the beam, under the weight. There are diagonal strains in all parts of the beam except this central point, and diagonal strains should transmit the polarized rays as well as the horizontal ones. That there are diagonal strains in all parts of the beam, although they may be very small in the upper end corners, may be shown by supposing the whole to be divided into very thin horizontal laminæ. The flexure of the beams by the weight would then cause all of these to slip one upon the other. This is resisted in the solid beam by the diagonal resistance of the material. The additional element of strength referred to in the paper, is, I apprehend, not due to the absolute resistance of the material to the sliding of the laminæ upon each other, or the "horizontal shearing strength" as it has been called, but to the elastic yielding of the fibres of the material, which, without diminishing their ultimate strength, allows them to slip, so to speak, upon the next interior fibre, so that the latter are drawn to a greater tension, or subjected to a greater degree of compression than they would be if there were no such lateral elasticity between the fibres. The outer ones would be ruptured as soon as their limit of elasticity was reached, and before a full strain was brought upon any of the interior fibres, were it not for this action.

Gen. J. G. Barnard.—I am disposed to think Barlow's position untenable, that the neutral axis *cannot* be in the centre of gravity, when the breaking strain is in excess of the result given by formula founded on that assumption. There is no more radical law of mechanics, than that the forces across any section must be in equilibrium. Take a cross section of a beam, and these forces cannot be in equilibrium if the neutral line is through the centre of gravity when the breaking force is found to exceed that due to tensile strength of the iron.

HYDRAULICS OF GREAT RIVERS.*

Condensed from the "Edinburgh Review."

It would be difficult to point out any part of the world, in which it is of more importance that the laws which regulate the flow and escape of water should be thoroughly understood than in Great Britian. The question comes practically home to us all. In our stormy and uncertain climate, the very aspect of our architecture betrays the fact that protection from rain and snow is one of the first objects of the builder. On the capricious character of our rainfall, the growth and the ingathering of our crops primarily depend. The course of commerce, filling with its wealth our noble and numerous harbors, is intimately dependent on the hydrographical advantages which they afford. For a large area of fen district in the Eastern Counties, man yet maintains a struggle with the sea, and with the land floods, hardly less precarious than that which has so long taxed the resolution of the sturdy Dutch. For the comfort of our homes, for the yield of our harvest, for the supply of our towns and cities with a prime necessary of life, and for the securi'y of our commerce, we depend on the hydraulic skill of our engineers.

We shall be safe, at all events, in assuming the position, that it is highly essential that hydraulics should be thoroughly understood in this country. The question, how far this is actually the case, is, however, altogether different. It is one to which a reply is, manifestly, important. But that reply should not be lightly hazarded. It is one as to which it is worth while to take some degree of trouble, in order to arrive at certitude. Our health, our comfort, our prosperity; the amelioration of our climate; the yield of our agriculture; the facilities for our manufactures; the requirements of our commerce; are all so intimately dependent on a thorough knowledge of hydraulic law, as well as of hydraulic practice, on the part of our engineers and architects, that the question whether our command of the subject is really the best attainable by the human mind, is one of great interest to us all.

We have good grounds for forming the opinion that the laws of hydraulic action are far from being thus thoroughly understood, even by the professional and scientific men of England. We may be challenged, as we are of course aware, for a scientific justification of this doubt. But before entering into an inquiry that may tend to become somewhat technical in its nature, we will offer a reason why, at the first glance, it is not unlikely that our knowledge is imperfect.

In all natural science there exists a broad distinction between phenomena of a delicate and exact nature, that may be made the subject of careful experiment; and phenomena on a scale of magnitude and grandeur that can be the object of observation alone. We may weigh, to the fraction of a grain, the water absorbed by a plant; we can only look on with awe at a sudden inrush of a great tidal wave. To a certain extent all our physical knowledge is experimental. However searching and comprehensive may be the action of physical force (as in the simplest and sublimest case, that of the great force of Gravity), careful experiment is a necessary preliminary to the determination of the uncontrolled applicability of that force in each instance. It is only when we obtain mathematical proof, that we are justified in ascribing the course of phenomena to the sole action of any great primary law.

Now when the laws investigated are of great magnitude, and of corresponding simplicity, much inconvenience may result from drawing inferences from experiments made on a scale that is comparatively small. It is far safer to reduce than to enlarge. From good observations, in cases where bulk, weight, and velocity are all very high (as in the movement of the planetary bodies), we may deduce rules applicable to cases of minor magnitude and movement, with much greater accuracy and safety than can be attained by the reversal of the process. It is far safer to predict the course of a small stream, or the effect of a small tide, from observations of a great river or a rapid sea, than it is to estimate the movements of the Atlantic from observations of the Mediterranean, or to gauge the flow of the Plata according to our experience of the Thames.

It is precisely here that the matter is brought home to our notice. M. Révy, a

* The Paraná, the Uruguay, and the La Plata Estuaries. By J. J. Révy. London; 1874.

member of the Institute of Civil Engineers of Vienna, has been consulted on hydrographic and hydraulic questions arising in the dominions of the Argentine Republic. There he found himself launched on one of the largest rivers of the world. Second only to that *regina fluviorum*, the Amazon, the Paraná and its affluents form the main outfall of a vast triangular area, bounded by the Andes on the west, by the southern watershed of the basin of the Amazon on the north, and by the mountain chains and ridges that flank the Atlantic coast of South America on the east. From the delta of the Amazon to that of the Plata, a range of thirty-five degrees of latitude, the rivers that enter the Atlantic derive their waters from a succession of broken and interrupted versants (the total area of which is but small when compared to the great central district, with its numerous ramifications) the unevaporated rainfall of which tends to the estuary of the Plata. The basin of the Amazon, with its *embouchure* lying on the equator itself attracts a heavier rainfall than that which visits any other portion of the surface of our planet. But its area is inferior to that of the watersheds converging on the Plata. It is to the greater depth of the equatorial rainfall, that the superiority of the volume of the Amazon, as compared with that of its southern sister, must be principally attributed.

The estuary of the Rio de La Plata, if we consider it to fall into the Atlantic at Monte Video, is nearly seventy geographical miles in width. Trending from the northwest, in a distance of 150 miles, it narrows irregularly, to a width of about thirty miles. At this point, the broad, deep channel of the Uruguay, lying on the meridian, makes a far more imposing show, as far as the map is concerned, than do the two less variable streams, or rather river mouths, by which, under the names of the Paraná Guayazu and the Paraná de las Palmas, the mighty central flood, stealing through its own delta for a distance of sixty miles from the division of the streams, enters the common frith.

The Uruguay, however, is rather a colossal torrent than a gigantic river. Its volume presents extraordinary fluctuations. It is at its lowest in December. About 200 miles above its mouth, or last contraction of width, at Higueritas, the Uruguay flows through a rocky channel, called the Corralito. The length of this natural canal is stated at about 700 feet; its width at 145; and a current of six feet deep, flowing at the rate of five miles an hour, represents the volume and flow of the river. This is rather more than two-and-a-half times the estimated summer flow of the Thames. But in the great periodical rise of the river, this fair-weather channel is completely submerged and lost to view. The great flood, which occurs in September and October, rises at the rate of three feet per diem, till it attains a height of from forty-five to fifty feet above the low-water line at Salto, a port two miles above the Corralito. The cross-section of the river, during flood, is more than five times that above estimated. But this proportion gives no idea of the increase of volume, which is due not only to the enlargement of the water-way, but to a more than tenfold increase in the velocity of the current.

The steady and constant flow of the Paraná forms a remarkable contrast to the violent fluctuations in the supply of the Uruguay. An immense body of water is constantly thrown into the Atlantic by the former noble stream, and its low-water supply never sinks, we are told, below the half of its flood. The geology, and even the actual area, of the watershed districts drained by these two great affluents are but imperfectly known. But we may almost venture to assert, from the evidence of these contrasted phenomena, that the Uruguay must be fed from a larger proportionate area of impermeable strata; while the main part of the water of Paraná is shown, by its steady flow, to have been subjected to the retarding and distributing action of subterranean storage and filtration. This at least, is our European, and we may say, our English experience.

The Paraná is the largest river on the surface of our planet of which we have any exact knowledge. For that knowledge we are indebted in no ordinary degree, to the patience and skill of M. Révy. At a distance of 200 miles from the island of Martin Garcia, which is situate on the La Plata estuary, at nineteen miles below the entrance into the water of the Paraná Guazu stands the town of Rosario, a place of some commercial importance, and the largest town on the banks of the river. "It is built," says M. Révy, "on the margin of the bluff, about eighty feet above the river, and the town reaches from the main land down to the Paraná. Some desultory attempts at

engineering stare at us in the shade of a number of strange structures, supposed to be piers; which a number of vessels anchored along the margin of the river seem rather to avoid than to court. Vessels drawing fifteen feet of water may come up as far as Rosario at all times, during the lowest level of the river. The rise of the Paraná from ordinarily low water to ordinary flood level is here about twelve feet, and the flood level is always maintained for three months."

Thirteen miles below Rosario occurs a straight reach of the Paraná about five miles in length. The width is 4,787 feet from margin to margin at low water. The depth increases, by a gentle and regular slope, from that of a few inches, on the left shore, to seventy-two feet, at a distance of about 1,100 feet from the right bank. Thence it rapidly shallows to about twelve feet, and then rises gradually to the foot of a vertical cliff forming the right-hand shore of the river.

At this point, three hundred and twenty miles above the junction of the Plata with the Atlantic, a series of measurements have been taken by M. Révy; to whom the students of hydraulics will hereafter owe no small debt of gratitude. The largest accurate measurement of any river section yet attempted, has there been carried out; under arrangements that reflect much credit on the engineers who have planned and accomplished the work. We wish to give our readers some idea of the grandeur of the river, before calling attention to the contribution made, in the present volume, to geographical, or rather hydrographical science. We shall therefore return, a little later, to the description of the method adopted for gauging the volume of the stream; only remarking that the cross-section, in this locality, of the ordinary flood of the river, gives an area of 243,000 square feet. This large superficies, however, is far from representing the entire water-way of the Paraná; as the left bank is, on occasions when the flood level is attained, submerged for many miles; and although the current over the hidden bank and islands is small, yet a considerable volume of water passes over the great additional sectional area. But even the ascertained section is hard upon the double of that occupied by the October flood of the Uruguay, before cited. In January, when the observations were made, the low-water sectional area of the Paraná was found to be 184,858 superficial feet; or, in round numbers, three-fourths of the area in flood time. The average depth of the section taken in January was forty-seven feet six inches; the extreme depth, seventy-two feet. At times of exceptional rises of the water, such as occurred in 1858 and 1868, this great depth has been increased by twenty-four feet. But that increase, although amounting to thirty-nine per cent. of the smaller dimension, represents not only a factor, but also a function of the second order of the increased volume of the flow. It is from the observations to which we now refer, that M. Révy has been enabled to indicate a new aspect of the great hydraulic law of the proportion of current to depth. We shall presently find that this ratio, is, at all events approximately, represented in this instance, by the ratio of the squares of the depths. That is to say, in round numbers, that the velocity of the Paraná in flood, is to its low-water velocity as 1 to 7.

If we endeavor to estimate the volume of water thus poured into the Atlantic, by any definite measures of capacity, we shall run the risk of attempting to grasp ideas, and finding that we have only succeeded in accumulating figures. The lowest unit that seems to be applicable to such enormous volumes is that of a million of tons. But who can present to his mind any accurate idea of a million of tons of water? We shall find a more illustrative, though still a very rough, mode of comparison by taking, as in the case of the Uruguay, the discharge of the Thames for a unit of comparison. We labor under the disadvantage that the most important discovery made by M. Révy, in the pursuit of his very elaborate survey, that of the law of the relation of depths and currents, was arrived at late in the course of his observations. The observations are sufficient to show the inaccuracy of the ordinary mode of calculation, and thus to prevent us from attempting to gauge the flow of a river by taking any percentage of the surface velocity as the mean velocity of the stream. Unfortunately, however, they are not accompanied by those measurements of the bottom current which this very experience shows to be so needful. It is therefore only approximately that we can estimate, from the details before us, the low-water flow of the Parana at 600 times that of the Uruguay; a movement

of water which is from 2.5 to 3 times that of the Thames, according to the highest estimate of its flow. In other words, the total body of water which the Thames pours into the Channel, in the course of a twelvemonth, is only equal to that which passes the Rosario section of the Parana, in less than twenty-four hours. Again we seem to arrive at the limits of the receptive power of the imagination, in dealing with such enormous volumes.

A comparison of no trifling interest may hereafter be drawn between the natural scale which has been formed, for the decipherment of future geologists, by the Parana, and the corresponding record inscribed by the Nile. From the first cateract (which may be compared in some respects to the Decimante mouth of the Parana), to the northern limit of the delta of the Nile, is a distance very closely according with that from Decimante to Monte Video. In each giant river a double system exists, that of valley course, raised by deposits from the water, and that of estuary. But in the Nile, owing partly to the comparatively narrow bed afforded to its flood, and partly to the different physical conditions of the two rivers, the seaward part of its course is that in which the largest deposits occur. In the Paraná the reverse is the case. The delta of the Nile may be roughly measured as a triangle of some 100 miles in altitude, and as many in base. The unfilled part of the sea channel of the Paraná, which is the Plata estuary, is 150 miles in length, by from 70 to 50 miles in width. It is not only in the division of the longitudinal course of the river into valley and estuary, or land formed, and land in the course of formation, by the deposits of the current, that the Paraná resembles her mysterious African sister. The union of steady, perennial, flow from a distant head-water, with periodic flood, thrown in from a distinct affluent, which is displayed by the confluent streams of the Nile and the Atbara, may be noticed in the confluence of the Paraná and the Uruguay. The length of the Parana, indeed, is only estimated at some two-thirds that of the Nile; but the volume of its flow appears to be far greater. A considerable allowance has to be made for the greater loss, by evaporation, to which the Nile is exposed in the course of a thousand and more miles of tropical flow. But the enormous volume attained by the Paraná, in its highest or extraordinary floods, exceeds anything which the hydrometer has yet attempted, with any approach to accuracy, to estimate. M. Révy has remarked, as before cited, that the summer flow of the Paraná never falls below half of its winter ordinary flow; the latter, we learn from the sections, rises twelve feet above summer level. But the great floods rise to twenty-four feet, and the additional velocity at which, in accordance with the observations of M. Révy, to which we shall presently refer, this increased volume flows, is such as to give a result of truly colossal magnitude. From M. Révy's data we can estimate the summer flow of the Paraná, at Rosario, at forty milions of metric tons per hour; the ordinary flow at eighty-three millions of tons per hour; and the great floods at 169 millions of tons per hour; or four times the summer flow, independent of the escape over the marshes.

We have been led to linger on the descriptive portions of M. Révy's book, partly by the fascination which is exercised on the mind by the extraordinary magnitude and grandeur of the scenery and natural phenomena observed; and partly on account of the weight that is given by that magnitude to those scientific deductions which give to the work a high professional value. We will endeavor to give the gist of the discoveries of M. Révy, in language that shall be intelligible to the general reader. The engineer we refer to the work itself, as a model of exact field notation, illustrated by clear and elegant diagrams. Nor can we fail to note the unusual excellence of the workmanship by which the lithographer, Mr. Thomas Kell, has so nearly approached the beauty of copper-plate engraving.

Rivers, it is trite enough to remark, are generally regarded as running, more or less, down hill. That their velocity depends on the fall, or gradient, of the valleys, to the bottom of which they betake themselves, is a no less self-evident proposition. But we can well understand that the general slope of a valley may be seriously interfered with by local obstacles. In our own Cumberland and Westmoreland lakes, as well as in many other parts of the world, the traveller may observe, from some commanding situation, how rocks rise, or hills seem to have been thrown down, across the mouth

of a valley; with the result of damming up the waters of the stream, into those placid expanses that lend so peculiar a charm to the landscape.

The occurrence of lakes, in the actual course of a river, may explain the reason why we are in the habit of measuring the velocity of streams by the inclination of their surface rather than by that of their channel. As water obeys the great law of gravitation, with a more unhesitating precision than any other material on which we are able to experiment in mass, we have no difficulty in calculating the theoretic velocity of the surface of a river, from its actual inclination, or fall per mile or per foot. So, on the other hand, we may arrive at the rate of that inclination, from accurate measurement of the velocity of the current.

Thus far all is plain and simple. But the question arises, what is the total flow of the stream, or what is the relation between the velocity of the centre of gravity (that is to say of the mean flow of the actual volume) and the velocity of the surface-current?

In attempting the solution of this question, we have to inquire what it is that tends to retard the flowing of a river. We know that falling bodies increase their velocity, in a known proportion, according to the time occupied in their fall. We are aware that this law of freely-falling bodies, applies to bodies that run or glide down a slope or inclined plane. Thus if a railway carriage be set in motion on the top of a long steep gradient, such as that of the Lickey incline near Bromsgrove, it gently creeps downward for the first few yards, mends its pace as it advances, and acquires a dangerous and irresistible speed as it reaches the foot of the plane. The cause that prevents a similarly marked increase in the velocity of a stream, when the inclination is continued, is the friction of the water against the sides and bottom (chiefly against the bottom) of the channel. In a rapid and rippling brook, when a child rakes up the sand from the bottom, or a fisherman throws a handful of groundbait into the water, it becomes at once apparent that the upper portion of the stream *overruns* the lower currents. The bottom drags back the flow, and the river is perpetually running *over itself* from top to bottom. Thus, of two particles of water, one at the surface and one at the bottom of the stream, the former is constantly gaining on the latter, and, in the course of a mile or so, will have left it far behind in its seaward course.

It is this relation between the top and bottom flow on which depends the actual discharge of a river. The subject is one that has by no means been neglected. Distinguished men have made experiments in order to gauge the flow of rivers; and the results of their observations have been embodied in certain mathematical formulas, which, if not absolutely identical, do not very materially differ from one another in their results, when applied to our modest English rivers. They are chiefly based on the experimental data of Du Buat, with additions by subsequent investigators. The formula of Weisbach is that quoted by Professor Rankine in his latest and posthumous work, the "Mechanical Textbook." The object of that formula is to ascertain the proportionate friction of a stream on its bed, represented by what is called the coefficient of friction. This formula refers to velocity alone, and only relates to depth in a roundabout way; that is to say, as it is indicated by velocity. The direct importance of this relation appears to demand more distinct recognition. It is not surprising that M. Révy found hydraulic formulas, based on observations of smaller rivers, to be inadequate, when he sought to apply them to the mighty flood of the Paraná; or that the great Mississippi survey should have been deprived of its anticipated value by the imperfection of the mode of measurement adopted by the surveyors.

It soon became clear that any attempt to ascertain the volume and flood of a river like the Paraná, by empirical formulas, was nothing more or less than guesswork. Actual measurement of widths, depths, and velocities was indispensable. The method adopted by M. Révy for ascertaining the cross-section of the Paraná, by a combination of soundings and sextant observations, may be studied with advantage in any hydrographic survey. If it cannot be called altogether novel, it is highly commendable, as an example of exactitude, alike in rule, in habit, and in expression. For the measurement of the velocity of the stream, as to which the ordinary clumsy expedient of floats could give no reliable data, an instrument called the current-meter was employed. This resembles a little mill —windmill, we were about to say, but at

all events a vane—of a foot in diameter, which is turned with rapidity when immersed in a running stream. The axle of the vane gives motion to a small train of wheels, which move a couple of indexes; as in a gas-meter, or as in a watch. These indexes denote the number of revolutions made by the vane; which is kept at right angles to the stream by a sort of rudder attached to the meter.

M. Révy does not claim the invention of the portable means of observation: but he has introduced two important improvements in the method of using it. One is, that instead of trusting to the ingenuity of the maker, to convert revolutions into feet and furlongs, the actual reading of each meter should be ascertained, by moving it through perfectly still water for a measured distance. This furnishes an equation for the instrument, allowing for the loss by friction, which is constant, and not proportionate to the velocity; so that the exact number of revolutions is booked on the spot, and the reduction into length is made afterwards. The other improvement consists in the attachment of the meter to an iron bar, six feet long, which M. Révy calls the current integrator, which can be raised or lowered at will from a boat, so as to ascertain the velocity of the current at any required depth.

The bulk of the observations made upon the currents of the Plata, the Paraná Guazu, the Paraná de las Palmas, and the Uruguay, were surface velocities alone. It was supposed that, from these observations, the mean velocity might be ascertained by formula, as before mentioned. In dealing with phenomena of such magnitude, however, an important fact became apparent. The velocity of the river, at any given cross-section, proved to be directly proportionate to the depth. Thus if a shoal occurs in the middle of the channel, the velocity of the current over the shoal is less than that of the deeper water on either side; and this diminution of speed is proportionate to the loss of depth. So direct is this relation, that a plan of the surface velocities, if projected on the appropriate scale, coincides very closely with the section of the bottom of the river. Any want of parellelism between the two curves is capable of explanation, either by the curvature of the banks, or by some physical irregularity of the channel.

This important law, now for the first time brought distinctly forward, renders the actual measurement of under-currents an evident necessity. But the grand result of the subaqueous measurements was not perceived in time to allow of the more extended experiments which are still requisite for the full elucidation of the subject.

So far as the actual experiments go, the result was, first, that the greatest rapidity of the current is at the surface, secondly, that the increase of this rapidity is in the simple ratio of the distance from the bottom. Thus, both by calculation and by measurement, the mean velocity of a stream at any part of its width, occurs at half the depth of the water, at that part, from the surface.

This result is so consistent with the former law, that the surface velocity is proportionate to the depth, that it might even have been arrived at by analysis. But it is incomparably more satisfactory, in the present state of our knowledge, to have the testimony of direct experiment.

No small increase of professional knowledge is thus gained. But now occurred an experiment which seemed, on the first blush, to run counter to the theory. In two successive measurements of the current of the Plata, the apparent anomaly was detected, that a decrease of the velocity of the surface current was accompanied by an increase of the velocity of the bottom current. Such an unexpected contradiction of an accepted theory would have been set down by nine men out of ten to error of observation. The field-book would, very likely, have been "corrected"; that is to say, *cooked*, and the fatal expression, "we know that cannot be right," might have strangled a discovery, the importance of which to the study of hydraulics it is not easy to over-estimate.

M. Révy, however, is evidently a man who has great veneration for truth. He relies, and justly relies, on the accuracy of his observations, and on the acuracy of his record of these particulars. He has that prime qualification of the great discoverer —philosophic patience. He prefers to confess ignorance, and to wait for knowledge rather than to invalidate actual observation, by forcing it to fit the theory. And he had his reward. It was owing, not to any special experiments, but to the general systematic excellence of his arrangements that he obtained the clue to this mystery. He found that the water of the Plata was act-

ually sixteen inches deeper, on the occasion when the under-current was more powerful. Here was a third, and most unexpected case, of the great law of the dependence of velocity on depth. The river was actually flowing in greater volume at a time when, to a superficial observer, it was slackened in its course. We can readily understand that the water was banked up by its own mass, and that the surface-fall at the point measured was, therefore, less than on the preceding occasion. In obedience to known hydraulic law, this decreasing surface-inclination was indicated by decreased velocity of surface-current. But the power of the whole moving mass of water was greater, in proportion to its depth. And thus, while to the superficial gaze the velocity was less, the mean velocity was greater, and the river swept with more resistless energy over its bed. This luminous observation is the opening of an entirely new chapter in hydraulic science. It is, in fact, a case of the law of the relation of speed to depth; but it is one that could scarcely have been arrived at by theory; although now that it is experimentally ascertained, its theoretical reason is ascertainable.

At this point M. Révy has paused. He might well have gone a step farther; but the modesty of his conclusions is perhaps as remarkable as their importance. He has drawn up no formula as the result of his observations. To explain and justify such a formula would, he tells us, require a separate treatise. He has been content to bring his observations before the world. He attacks no one; he corrects no one. He desires no one to control their observations by his. He simply says such and such were the facts, on such a day in such a locality. He places the raw material of science in the hands of his professional brethren; and invites them to make as free a use of it as he does himself. He truly says that the facts recorded in his pages will supply ample material for the contemplation of those who love their profession for its truth and for its beauty.

We are not satisfied without taking a step farther. We must be cautious not to generalize too hastily. We cannot endorse the observations of M. Révy on the subject of mean hydraulic depth. To these mighty rivers the retarding influence of the sides of the channel is almost unfelt. But we cannot doubt that it exists; and that it is improper to neglect that fact, especially with reference to smaller streams. We must hesitate to deduce great laws from a very limited number of observations. But, on the other hand, when we regard each new position, laid down from observation of the movements of these great masses of water, as presenting a distinct case of the same law; and when we find authentic results accurate, within the limit of precision of observation; we think it well, under due reserve, to indicate the upshot of experiment. By comparing accurately the volume of flow of the Plata, on the two occasions above described, making due allowance for the retardation by loss of head, we find the increased mean velocity of the river to be in exact ratio of the squares of the depths on the two days under investigation.

If this very simple rule be ultimately shown to be normal, the results that it will have on our hydraulic engineering will be marked and precious. Thus in the recent proposals to draw a new water supply for London, from the watershed of the Severn, of the Wye, or from the Ulswater system of lakes, we find one engineer propose a canal of 30 feet wide and 10 feet deep for the main stream; and another, one of 15 feet wide and 14.5 feet deep for a not very different quantity of water. The fall in the latter case is estimated at from sixty to twenty-four inches per mile. But with such a variation of level, the cross-section of the channel must be proportionately increased or diminished. And, surface inclination being the same, although the sectional area of the last-named conduit is only about two-thirds that of the former, the actual delivery, according to M. Révy's observations, owing to the increased velocity due to the extra depth, would amount to more than that of the shallower acqueduct. Not a glimpse of such an idea appears in the report of the Royal Commission of 1869 on water supply. Here the observations on the Paraná come home to us with much interest. There is another point untouched by M. Révy, but which his observations are calculated to suggest. He speaks of the bottom-flow of a river being possible at any velocity, from zero up to the surface-flow. We do not see that the upper limit is definite. At the mouth of the Paraná, where the channel is only half a mile wide, and where even the di-

vided body of water represents a mighty volume, not even a ripple is perceptible on the surface. As we read the description, there is no evidence of perceptible surface-current, or of sensible head of water. If this be so, the under-current may be powerful, while the surface-current is *nil*. We must have this important question elucidated, by means of the sounding lead and the current meter; nor can the matter be alowed to rest until this be done.

Again a question arises, of no little importance to the hydrographical department of the Admiralty, as well as to the science of physical geography. We have heard at times, of an under-current in deep water at the Straits of Gibraltar. The escape by an under-current, from the Black Sea, of some portion of the enormous contributions poured into its waters, has been more recently suggested. The ascertainment of the exact facts, in each locality, which the use of the current integrator renders easy, ought not to be postponed. We trust that the Admiralty will show promptitude in obtaining and affording the information, which is thus shown to be within its grasp; such an investigation will throw much light on the subject of Mediterranean evaporation, and on the hydraulics, not only of great rivers, but of the sea itself.

It cannot be considered as a circumstance redounding to the national credit—although it is highly to the credit of distinguished individuals—that we are dependent on *amateur* exertions for the knowledge that we possess of the rainfall of England and of the kindred questions that affect the origin of our rivers. More than 1,500 private observers now contribute daily observations, on which Mr. G. J. Symons bases his Annual Tables of British Rainfall. The value of these observations may be estimated from a knowledge of the wide difference that exists between the annual rainfall at stations not very widely distant from one another. Thus at Stye Head Pass, in the Westmoreland district, 243.98 inches of rain fell in the course of 1872; or upwards of 20 feet of water; a depth greater than that which we now estimate that the evaporative power of the tropical sun draws up from the surface of the ocean. During the same year, the rainfall measured at Silsoe was only 26.18 inches. When we find that the spirited and unremunerated efforts of men, who follow science only for the love of truth, are thus active, it would be ungracious to grumble at the want of conclusive observations as to evaporation, as far as they are concerned. But we find that Mr. Miller, who has made uninterrupted observations on the evaporation from water, for eleven years past, is still unable to give constants of evaporation.

An unusually favorable opportunity presents itself for the actual determination of the most steady and remarkable case of evaporation that occurs on the surface of our planet. In its headlong course from the foot of Hermon, the Jordan (well-named the descender) may almost be said to consist of three continuous cataracts, divided by two lakes, and terminating in a third. From the surface of that bituminous sea, the water of which contains nearly one-fourth of its own weight of salts, the whole supply brought down by the Jordan and its affluents is exhaled in invisible vapor. With the increased supply, when the swollen river overflows its banks, the waters of the Dead Sea rise, and its surface extends, until its area is such that the evaporation again balances the flow. The steady pulsations of this great natural hygrometer deserves the most attentive study. The Ordnance Survey of Palestine, the rapid progress of which promises to enrich our atlases with a map of unusual precision and beauty, may be expected to supply exact information as to the area of the Dead Sea at different seasons of the year. If with this is connected an accurate measurement of the volume discharged by the Jordan, we shall be furnished with evaporative data of the highest value. We admit that the geological features of the spot are of unrivalled interest. We trust that careful surveys may throw much light on the original course of the drainage, from the North of Syria into the ancient embouchure of the river at Akaba. It is far from unlikely that a connection between geological action, and historic dates, as marked as that which has rendered famous the Temple of Serapis at Pozzuoli, may here be detected. But whatever may be the results of exploration, in a geological or an archæological direction, we cannot but express the hope that the valuable data, which this district offers to meteorological science, may be now exhaustively collected. If we are taught hydraulic laws by the Paraná, we may increase our knowledge of the laws of evaporation from the survey of the Dead Sea.

THE DRY EARTH SYSTEM.

From "Iron."

The disinfecting powers of common earth have been known from time immemorial. The ancient Israelites, probably without knowing the cause, were as familiar with the results as we ourselves are. And those curiously unprogressive people, the Chinese, have always been acquainted with the fact that the mixing of earth with excreta render the latter innocuous. The lessons thus taught in the past have, however, been neglected with us until the last few years, when an apparently accidental disposal of the excreta of a private house led an English clergyman to make a number of experiments, which led to the invention of the dry earth system—one of the most, if not the most, successful of the many devices yet resorted to for dealing with this important subject.

In the year 1858 the Rev. H. Moule, vicar of Fordington, in Dorsetshire, was troubled with the nuisance caused by the cess-pool of his house. Like almost all cess-pools and middens in this country, it was close to the well, and thus threatened the complete pollution of the water which the family had to use for all domestic purposes. To obviate this danger, and to get rid of the nuisance, Mr. Moule abolished privies and water-closets, and placed small buckets beneath the seats for the reception of the excreta, the contents of which were regularly emptied into a trench made in his ground for that purpose. In a short time he discovered that the effect of the earth on the excrementitious matter was to totally deodorize and disinfect it. This discovery led him on a step further in his experiments, and he now mixed dry sifted earth with the contents of the buckets, which were then emptied and left in a shed to consolidate. In an account of his proceedings, furnished by Mr. Moule, it is stated that "About three cart-loads of earth were used in this manner during a period of five or six weeks, for a family of seventeen persons, and at the end of that time he found that the first portions of earth were sufficiently dry to be used again. It was while using the same earth for the fifth time that he published the results of his experiments, and inaugurated his system—saying that it was founded on the rapid and effectual disinfecting powers of dry earth; in the capability of using the earth again and again, until it became soil as a manure; and on the fact that the system dealt with the sewage and cess-pool difficulty at its very source. He then devised the mechanical means of using earth in an ordinary closet or commode, and in 1860 he obtained a patent for it. He ascertained that a pint-and-a-half of dry earth was sufficient for each visit to the closet."

This system has now been tried in many places in England and in India, and always with success. In our great Indian Empire it has secured for itself a permanent position, and its use is authorized by the Government, and a grant of £500 was made to Mr. Moule by the Governor-General in Council, and sanctioned by the Secretary of State for India.

Messrs. H. J. and J. W. Girdlestone, civil engineers, state that by a long series of experiments, the following facts have been tested and re-tested, and at length completely established as principles:—1. That any surface earth, and almost any clay, will deodorize excrementitious matter; but that mud and chalk will not. 2. That such earth, if dried and sifted, has such power of absorption that it is capable of receiving both liquid and solid excreta, and of rendering their removal practicable without offence, and also without any loss to the value of the manure. 3. That a very small quantity of earth is required, and that the same portion of earth may be repeatedly used with the same effect. 4. That the action of the earth on the excreta is immediate, all fermentation being prevented, the obnoxious agent being dealt with at once, and in detail. 5. That, while the earth absorbs the excreta, they in their turn possess a decomposing power such that any extraneous matter deposited with them disappears in a short time. 6. That the absorption and deodorization of the excreta result in preventing infection.

This system is now at work at a large number of public institutions, as well as having been applied to a still larger number of private houses in this country. Among the places now using it we may mention the Lancaster Grammar School, the Dorset County School at Dorchester, St. Mary's College, Oscott, near Birmingham, the Broadmoor Criminal Lunatic Asylum, the Sanatorium at Weston-Super-Mare; at several villages on the estate of Baron Rothschild, near Wendover, in Buck-

inghamshire, and at, notably, the volunteer camp at Wimbledon. The last-named place may be safely selected as an illustrative example of the efficiency of the system for the experiment there was, in fact, a crucial one. In the *Lancet* of August 1, 1868, the result is desribed in the following words: —"The strongest possible testimony has been borne to the efficiency of the 'dry earth system,' which was in use throughout the volunteer encampment at Wimbledon. Last year the system was experimentally tried, and resulted so satisfactorily, that it was determined to adopt it this year exclusively. There can be no question that the test to which the system has been subjected was a crucial one, considering especially the excessive heat, which, although favorable to the rapid drying of the soil, was yet creative of other conditions increasing the difficulties attendant on fæcal deodorisation. Altogether some 148 dry earth closets and urinals were in operation at Wimbledon, and when it is remembered that about forty or fifty of these closets were used daily by not less than 2,000 men, without the slightest annoyance to sight or smell, the measure of success is complete. It is not too much to say that no other system is possible at Wimbledon, where circumstances have all to be made to square with temporary requirements. But if the dry earth closets can stand the test of such repeated use as they have lately had, it seems to us to follow as a matter of course, that they must be in every way suitable for the exigencies of rural districts."

Dr. Buchanan ascertained, from careful inquiry at the Camp, "that during the meeting of the volunteers, which lasts for fourteen days, as many as 3,000 persons use the closets daily, and 10,000 the urinals. In the course of that time 140 tons of dry earth are expended in the closets and urinals, the closets requiring 4500lb. per day, and the urinals 17,900lb. This is in the proportion of 1.5lb. of earth for each operation at the closets, and 1.79lb. for each visit to the urinals. When the earth was dry and of good quality it was found that the product was solid and inoffensive; but when, as in the preceding year (1867), it was of a peaty nature, the compost was wet and warm. Taking these facts into consideration, Dr. Buchanan concludes that 4½lb. of dry earth would be a proper supply for each person daily, 1½ lb. being allowed for each visit to the closet or urinal, and three such visits daily. A village of 1000 inhabitants would, therefore, require 500lb., to just two tons of dry earth per diem.

In the month of January of the present year (1874), we paid a visit to the Sanatorium at Weston-super-Mare, at which the dry earth system is in use. We examined the process, and from all the information which we could obtain on the spot—and this was given in the fullest and freest manner —we could arrive at only one conclusion. The system had proved in the highest degree satisfactory and successful.

As regards the value of the product, we learn, on the authority of Dr. Letheby's "Notes and Analyses," that it seems, "like all such materials," to be variously estimated, according to the quality and the demand. In the City of Lancaster, where the material is mixed with the refuse of the shambles, and with urine from some of the public urinals, it realizes only from 7s. 6d. to 10s. per cubic yard, and it just pays its expenses. At the Dorset County jail it sells for £1 a ton, or 10s. per head per annum; but at the county school in the same town, it fetches from £2 to £3 a ton, or 15s. a head. In the experiments of the Rev. H. Moule with material that had been used in closets five times over, it was found that, when contrasted with super-phosphate at £7 12s. a ton, its immediate results were equally good, and its permanent effect on the land much better. In both cases the manures were employed in the same quantities—namely, in the proportion of 1 cwt. to an acre of land. We are not acquainted with many chemical analyses of the product, although two have been published by Dr. Hawksley, which were made by Mr. Evans, of Leadenhall Street, both of them being of material that had been used only once in the closet, and the results are as follow:—

Organic matter, &c.	5·16	22·65
Soluble phosphate of lime	0·53	1·10
Potash	1·06	1·10
Alkaline salts	—	4·10
Aluminia, sand, &c.	—	71·5
	100·00	100.00
Nitrogen equal to ammonia	0·33	0·79

These samples were valued by Mr. Evans at £1 and £1 10s. per ton respectively: but it is evident that if the material had been used four or five times over, it would have

been considerably more valuable than this."

In his report to the Privy Council, Dr. Buchanan gives the following summary of the advantages of this system: —

"(1.) The earth closet, intelligently managed, furnishes a means of disposing of excrement without nuisance and apparently without detriment to health.

"(2.) In communities the earth closet system requires to be managed by the authorities of the place, and will pay, at least, the expenses of its management.

"(3.) In the poorer class of houses, where supervision of any closet arrangements is indispensable, the adoption of the earth system offers special advantages.

"(4.) The earth system of excrement removal does not supersede the necessity for an independent means of removing slops, rainwater, and soil-water.

"(5.) The limits of application of the earth system in the future cannot be stated. In existing towns, favorably arranged for access to the closets, the system might at once be applied to populations of 10,000 persons.

"(6.) As compared with the water-closet the earth-closet has these advantages: — It is cheaper in original cost, it requires less repair, it is not injured by frost, it is not damaged by improper substances being thrown down it, and it very greatly reduces the quantity of water required by each household.

"(7.) As regards the application of excrement to the land, the advantages of the earth system are these: The whole agricultural value of the excrement is retained; the resulting manure is in a state in which it can be kept, carried about, and applied to crops with facility; there is no need for restricting its use to any particular area, nor for using it at times when agriculturally it is worthless; and it can be applied with advantage to a very great variety, if not to all, crops and soils. After the disposal of excrement by earth, irrigation will continue to have its value as a means of extracting from the refuse water of a place whatever agricultural value it may possess, for the benefit of such crops and such places as can advatageously be subjected to the process.

"(8.) These conclusions have no reference to the disposal of trade or manufacturing refuse, which it is assumed ought to be dealt with as belonging to the business in which it is produced, by the people who produce it, and not to come within the province of local authorities to provide for.

VENTILATION;

WITH SPECIAL REFERENCE TO THE TURRET-SHIP "DEVASTATION."

By M. Blank, Esq., R. N.

From the proceedings of the Junior Naval Professional Association.

The subject of Ventilation, especially in connection with the latest novelty in armor-plated turret ships, cannot but prove an interesting one for consideration by the members of this association. We are all vitally concerned, and have probably at some time or other, suffered from living in a vitiated atmosphere, the result of imperfect ventilation, or no ventilation at all. That the question is an important one, is now fully admitted, and it is a fact to congratulate ourselves upon, and the service generally, that it is beginning to receive the amount of attention it deserves.

In venturing to address you, my hope is, that the paper I shall have the honor to read, may serve chiefly as an introduction to addresses from gentlemen better qualified and more conversant with the subject. I can claim originality for no part of it, neither have I been able to cull largely from standard authorities, the absence of a public library being a drawback in preparing papers on anything approaching scientific subjects.

What do we understand by ventilation? a subject that has received its share of attention from learned Professors and scientific societies, few of them holding identical views, as to the mechanical, or other means to be employed. Let us divest it of all technical and theoretical complication and be content to know and speak of it as the necessary and simple operation of substituting one volume of air for another, by one of two processes, abstraction of impure air and the consequent substitution by grav-

itation of pure, or the forcing in by mechanical means of pure air, and the expulsion of impure.

It would far exceed the limits of the present opportunity, to recount the thousand and one modes employed to secure a change of air in our dwellings, public buildings, ships, &c., &c., we should but confuse ourselves in the multiplicity of ingenious, but often mistaken devices. One thing is certain, that in attempting any system of ventilation, the more nearly we copy the simple and beautiful operations of nature the more surely will success crown our efforts.

There was a time when the origin or causes of natural phenomena were mostly shrouded in mystery, and the effects ascribed to the influence of particular and presiding Deities; but in our day, thanks to the almost superhuman achievements of our students and philosophers in the varied and extensive domains of scientific research, we know that the elements yield implicit obedience to immutable natural laws, and that the rushing wind, and the gentle breeze, are alike due to a compliance with the fixed laws of gravity;—the rarefaction of air on one portion of the earth's surface, and the settling of colder and heavier strata to supply its place; and it is this simple natural law we must bear in mind, and upon which the entire principle of ventilation depends.

As an illustration, I would refer you to the old and time-honored system used to ventilate the shafts and workings of coal mines. The shafts and passages are merely divided by a partition called a bratticing, one side is used for the exit of rarefied foul air, and the other free for the descent of fresh. A fire is kept burning on the upcast side of the partition—generally at the bottom of the shaft—which rarefies the air, increases its bulk, and therefore decreasing its specific gravity; the balance is destroyed in the two sides of the shaft, the lighter and foul air giving place to the heavier and pure; and this will continue though the air may have to travel miles before it commences the return journey.

It is a great mistake to suppose that a space say the hold or lower deck of a vessel, can be ventilated by merely cutting large apertures or hatchways; nothing of the kind can be done, a diaphragm must be inserted. A fire placed on the deck would burn badly without the upward and downward currents which must be separated; the partition should go nearly to the bottom of the space and be carried high as possible above the aperture, then there will be ventilation.

Most of you have no doubt noticed the strong draughts of cold air rushing from the engine-room to the stoke-hole, that is produced by carrying a diaphragm—the bratticing of the coal mine—from the upper deck down as far as practical, the heat of the boilersand funnel rarefies the air inside the partition, it ascends, and colder air finds its way through the engine room from the lower deck; and from the outermost sides of the hatchways divided by the diaphragms, the supply of air for the furnaces is also brought by the same means.

This arrangement has been of incalculable benefit, and the credit of introduction, (not invention,) I believe is due to Mr. Baker, Chief Inspector of Machinery; it was perfected at Chatham by a long and careful series of experiments conducted by Admiral Halsted and Mr. Langley, Chief inspector of Machinery.

I think I may safely affirm, that with the exception of the simple but necessary arrangements for working mines, ventilation as a science is the offspring of the latter half of the nineteenth century. The laws and principles were undoubtedly known and understood, but rarely reduced to practice. In the mansions of the wealthy and the palace of royalty, the removal of impure air and the supply of pure was left to chance, or but noticed as of little moment, while in the cottages of the poor, the crowded dwellings of the masses, and the reeking stifling dens that harbor the refuse and dregs of our city populations, the gaunt demon of destruction stalked unnoticed and unchecked, his greedy maw supplied with a plenitude of miserable victims by those twin fell sisters—disease and crime. Even at the present time in this 16th century, the boasted age of civilization, of princely bequests and unbounded benevolence, millions of our fellow men are left to wither and rot, the victims of culpable ignorance or grasping criminal avarice; and even where efforts are made to remedy such short-comings, the stream of pure air that should be cherished as the breath of life is fought against as an enemy; and this is not confined to the lowest class, for how often do our medical men find their patients dying from want of pure air, with even the chance apertures of their rooms almost hermetically sealed. Unfortunately, ventilation so called is too often but a series of draughts which

are alike prejudicial to comfort and health, and at the present time particularly objectionable, when every combustible atom needed to supply the caloric for our internal economy and external warmth, is so much dearer. No wonder we so often see sickly inmates and smoky chimneys. Where is the air to enter when the chinks of door and floors are pasted over? And a few more coffin nails added in the shape of padding for windows, &c. The air can only enter in fitful gurglings down the chimney as it does in a bottle when fluid is escaping.

And what did our brave old salts of the Pigtail, or even down to much later eras, know or care for ventilation? How many of them succumbed to the dread unknown, and were unaccountably lost to the service—who shall tell! We know and remember with pride but their glorious achievements. True, they had the advantage of many safeguards absent at the present time; they were a more hardy and robust class of men than our present race of seamen; though the spaces between decks were more confined than ours, they lived more on deck, wore rougher and perhaps more suitable clothing, knew nothing of the modern effeminate custom of going aloft in sea-boots, wearing gloves and comforters, innovations we have to thank the Russian war for. The efficiency of the ship depended entirely upon their smartness and endurance, and they would no doubt have looked with scorn—especially our Pigtail friends—upon the dirty smoky kettles, inelegant double topsails, and patent reefing and truss arrangements; their arduous duties kept them on deck, and balanced the short-comings in ventilation.

They had their proper wind-sails, but these were chiefly used to dry their eternally wet and saturated decks. A properly constructed wind-sail, properly adjusted and trimmed, is invaluable on board ship; but the amount of attention it requires, its unsightly appearance, and the unfortunate faculty of always being in the way, renders it practically valueless.

I need not take up your time in proving the absence of ventilation in our wooden ships, our individual experiences being sufficient. I shall ever remember with loathing, being obliged to remain for some time on the lower deck of a frigate, during a tropical storm, all the hatch covers, &c., being on; it was something indescribable, something horrible.

At the present day, our commanding officers,—thanks to their greatly improved scientific education—are awakening to the fact that proper ventilation tends to the greater efficiency of the ship, by keeping down the sick-list. which reacts on the black list for a healthy body tends to a better mind, better feelings, and more cheerful execution of duty; and *vice versa*, for a sickly complaining man is a nuisance to himself, and of but little use to the service—in fact, he only infects his messmates with his own miserable dissatisfied spirits.

The authorities are insisting upon the strictest attention being paid to all matters of hygiene, and the medical officers upon whom the important duties chiefly devolve are equally alert and fully competent for the efficient discharge of those duties.

Were this enlightened spirit wanting, were these changes not the natural result of a higher culture and more liberal scientific training of our officers, they would have been made all the same; our modern men-of-war, from their peculiar construction, imperatively demand special ventilating arrangements: without, they would soon become mere floating prisons and hospitals, and alike dreaded and shunned by our seamen, and we all know what would be the consequence of a loss of confidence in their ship, either by officer or blue jacket.

In order to fully appreciate the necessity for ventilation and the difficult task imposed upon the designers and constructors of our dwellings on shore and afloat, let us glance at the approximate amount of air required for respiration by one adult person.

Blood, in a healthy condition, is charged with a certain amount of oxygen, during the circuit through the system, the oxygen is taken up and consumed; carbonic acid is formed, the blood becomes venous and unfit for further circulation, till on passing through the right side of the heart and the pulmonary arteries into the pulmonary capillary vessels, it comes into contact with the air drawn into the lungs, where the necessary amount of oxygen—about 4·5 per cent. of the inspiration—is taken up by the blood, and it passes on to the right ventricle, while the expiration takes with it in chemical combination the carbonic acid—amounting to about 3·3 per cent.—acquired by the blood in the grand operation of keeping the fuel in the human furnace in full and effective combustion, which would otherwise as effectually extinguish the vital spark

of human life, as the closing up of a furnace would an ordinary fire; as in the ever-memorable and fatal Blackhole at Calcutta, and in the too frequent suffocations by charcoal, each case the result of excess of carbonic acid.

Every person requires about one cubic foot of oxygen per hour, thus rendering five cubic feet of air unfit for respiration.

If ten men were confined in a room closed at all points, fifteen feet square and ten feet high, equal to 2,250 cubic feet, they would consume the whole of the oxygen in forty-four hours—that is, if they lived so long—but death would take place long before that time. Pure air contains only from 4 to 5 volumes of carbonic acid in 10,000 volumes.

I am unable to state at what point of saturation actual danger to animal life commences, but believe it varies in different individuals, depending upon strength of lung and constitution. We do know that no one can live where a candle will not burn, and flame is extinguished when there is 20 per cent. of carbonic acid in the air; but insensibility sets in long before that degree is arrived at, and there is no doubt it is highly dangerous to breathe air that has already passed through a system perhaps tainted with disease; for not only would the amount of each respiration be deficient in oxygen, but it would be charged with deadly carbonic acid, the pregnant cause of blood poisoning, in its various forms. Air containing 33 volumes in the 1,000, or 3.3 per cent. of carbonic acid has been taken from the lower deck of a vessel at night. Dr. PARKER says, "air containing from 50 to 100 volumes per 1,000 of carbonic acid is fatal to human life, but that a much lower per centage—say from 15 to 20 volumes per 1,000 would produce very serious consequences," the premonitory symtoms being headache, drowsiness, and quickened but less efficient action of the lungs.

From 3 to 4 per cent of carbonic acid is found in the air expired from the lungs; but as the atmosphere of the room becomes unduly charged with carbonic acid, the amount in each successive expiration perceptibly diminishes, thus leaving behind to poison the blood, the difference between the amounts due to perfect and impaired respiration, until the maximum point of saturation is reached, viz., 10 per cent, when common air refuses to absorb any more carbonic acid, the act of respiration becomes useless, and death ensues.

Five cubic feet of air per hour will supply one person with sufficient oxygen; it is calculated that for perfectly healthy respiration, with a mean of 16 respirations per minute, and a mean of 32.5 cubic inches per inspiration, a healthy person would consume 433 cubic feet of air in the 24 hours. A candle consumes the oxygen of $2\frac{1}{2}$ cubic feet of air, and every pound of coal the oxygen of 150 cubic feet of air, so that for every person in a room, there should be a supply per hour of 18 cubit feet of fresh air, for every pound of coal 150 feet, and for every candle or its equivalent $2\frac{1}{2}$ feet; from 50 to 100 per cent. should be allowed in addition for waste. The fact that a candle will not burn in an atmosphere dangerous to life is well-known, and often used as a test before workmen are sent into wells, or other confined places. On board ship the practice is necessary. No man should be sent into a boiler, bunker, or double bottom, that has not been examined for some time, without taking such a necessary precaution. A naked light is sometimes dangerous, for the gas may be of an explosive nature. Safety lamps are therefore now added to the complement of stores.

In attempting to prove the necessity for abundant ventilation, I have taken no cognizance of the effect due to exudations from the skin; this, though of very great importance in any consideration of the question, I am unable to deal with, not possessing the necessary data.

The novel construction of the *Devastation* has necessitated the introduction of a most elaborate system of artificial ventilation, as with the exception of wing passages on the breastwork deck, scarcely any room or compartment could depend upon natural means for supply of air; but though the arrangements are so elaborate and extensive, so far as the supply of fresh air is concerned, the whole is simplicity itself. Fresh air direct from the flying deck is forced by five fans into main trunks, and each and every compartment, cabin, store, magazine, mess-room and office is connected with them, and can regulate its supply of air at will, exactly as in towns, the water and gas companies lay down mains and branches from them to individual houses, to be drawn from at the will of the occupiers; so that in the ward-room, where there are four 3-inch pipes, one in each corner, and fitted with stop-cocks, if the room becomes too warm, instead of ordering the skylights or doors to be

opened, the order will be, "turn on a little more air please," or the facetious member of the mess will request the introduction of a little more oxygen, ozone, &c., &c.

To attempt a thorough and precise description of the whole system of mains and branches in their various ramifications, would require much more time—and I am afraid patience—than we have at our disposal, as well as a series of sketches and drawings with which I am not provided.

The fans are five in number, and are on and under the deck next above the engine compartment. Two are placed on the forward side of the water-tight bulkhead dividing the engine-room from the after stoke-hole, one is on the after side of the bulkhead dividing the forward and after stoke-holes, and two on the forward side of the same bulkhead.

The engines for driving them are placed on platforms, two in the after part of the engine-room, the rest in the upper part of the stoke-hole, below the fans; the motion is communicated by means of bands passing up from the engines to the drums on the fans. The steam for the engines is supplied by the auxiliary boiler, or from the main sets if in use. The fans are "Lloyd's Patent Noiseless Disc Fans," the impeller being 48 inches in diameter, and requires an engine of about 8 horse-power to drive them at a speed of from 800 to 1000 revolutions per minute, when they will discharge at the rate of from 10,000 cubic feet of air per minute, which may be either *pure* air to force into the ship; or by attaching the main trunks as suctions to the central orifices, and opening the discharges into the air shafts to the upper deck, foul air may be abstracted from any part of the system of pipes, or one set might be used to supply fresh air, and the other to abstract an equal amount of vitiated air.

If all the fans are working full together, it would be possible to force into the ship from 50,000 cubic feet of air per minute. The suctions are placed in special air shafts open to the flying-deck, and closed to the rest of the ship, thus ensuring complete isolation from ascending air and gases from the decks and holds below.

The discharges lead into main trunks 22 +15 in area (sectional) all connected with each other, so that the pressure from all the fans will be equalized, or one fan would supply air to the whole system of pipes. One fan may also be used to supply air to the stoke-holes only. They are all provided with stop-valves to prevent the air escaping through a fan that may not be at work.

Sluices are fitted so that each compartment can be shut off in the event of an accident, the same as those below for other services. This arrangement is necessary to meet any emergency, but it is not complete, for suppose the compartment next abaft the engine-room to be cut off, the compartment next abaft that, and the whole after part of the ship would be deprived of ventilation, not at all a desirable state of things under any circumstances.

This might be avoided by having fewer openings into the main trunks, and those fitted with balanced self-acting stop valves, that would open easily to the entering air, but would close to any back pressure. Every supply pipe is fitted with a stop-cock, but it would be a work of time to close them all, and a most uncertain method. The arrangements for the magazines are a case in point. The supply for them is taken from the same branches that serve the screw passages. Suppose the compartment enclosing the screw passage to be flooded, unless every cock in the passage flooded, or those in the magazines be closed, water would undoubtedly pass from the one to the other—a most serious consideration. Some arrangement I think should be introduced, quite self-acting, to prevent a back flow of water through any of the mains, branches, or pipes.

In the magazines where there is no connection with any other compartment, special pipes are introduced leading to the upper deck to carry off the used air.

In the engine department, the ventilation is effected by the same system as described for most wooden ships, viz., diaphragms separating the upward and downward currents, supplemented in the stoke-holes, by eight air-pipes supplied from the main service, and a portion of the hottest air in the upper part compartments is drawn off by tubes carried up through the middle of the funnels, in the centre of which the waste steam pipes are placed; the annular space being a valuable addition no doubt.

In the engine-room there are apertures to be regulated at will in the main trunks, which pass through the *upper* part.

In the screw passages there are pipes from the main service three two-inch pipes in each.

The temperatures at the trial were, on

deck 55°, engine-room, starboard, 108°, midship 95°, port 107°, stoke-holes, forward 113°, midship 104°, aft 86°; after, forward 90°, midship 112°, aft 114°, and this on a comparatively cold day and half a gale of wind blowing so said the papers.

At the risk of being thought impertinent, I say that in my opinion, none of the provisions in this department are as perfect as they might be. In the engine-room the fresh air is admitted at the *highest* point, just over where you might expect a current of hot air from the cylinders to be battling for escape upwards; the orifices should be carried lower down, to prevent the wings from becoming burning fiery furnaces, though this defect might be remedied or mitigated considerably if a current of cold air could be discharged from the screw passages into that region, as is generally the case in ordinary vessels, most of them having air-shafts carried up by the screw-well to the poop, but here there is a very inadequate supply, there being only three 2-inch pipes in each screw passage.

At the trial the temperature was from ten to fifteen degrees higher at the wings than amidships, though it is at the sides where the cold air is admitted, proving a want of circulation.

In the stoke-holes the air pipes from the mains are led into the bilge, and through stoke-hole plates amidships, at intervals of 7-feet, eight in number, and discharge 18-inch from the plates; a good arrangement so far as the distribution of air is concerned, but I think it would puzzle any one to select a more inconvenient position, taking the duties and comfort of the men on the fires into account, they will be continually knocking their hands, or falling over them. I would suggest at the ends or between the boilers as more suitable places, or at least their being placed close alongside the iron columns, as I believe is the case in the *Sultan*.

There are two funnels and two sets of air spaces divided by diaphragms from the flying deck down into the stoke-hole, ending 9-feet from the plates; as it is fully established that the lower the partition can be brought down the more effective it will be. I think in this case if they were brought a few feet lower it would materially improve the ventilation.

The same remarks apply to the shafts for hoisting ashes, and in addition they would be much safer than at present, for when they are high enough, those on duty are very liable to take severe colds from standing under them, and there is also danger of being brained by falling ash-buckets. A short time ago an engineer passing one was seriously hurt by a bag of coal being dropped upon him. I was under the impression an order was issued at the time for them to be always carried as low as possible.

There are also six downcasts from cowls on the flying deck, leading through the uptake round the funnels to within 9 feet of stoke-hole plates.

The great importance of supplying an efficient system of ventilation for the engine department may be readily appreciated if we consider that more than 100 tons of coal can be burnt in the 24 hours, and that for the effective combustion of these alone no less than thirty-three millions of cubic feet of air is required for the bare chemical equivalent, but in addition to this, we ought to allow as a margin to meet the defects in construction, mismanagement of firing, &c., at least fifty per cent. more. The amount required for ventilation that would pass through the uptakes round the funnels may be taken at perhaps another fifty per cent., giving the enormous total of sixty-six millions of cubic feet, or at the rate of nearly three million cubic feet per hour or forty-six thousand per minute.

I will not attempt to dilate upon the tempting theme that here suggests itself, viz., that we are now speaking of the very vitals of the huge machine, and that the whole well-being of itself and the lives of its officers and crew entirely depend upon a maintenance of perfect efficiency in this department. I am sure there are those present who will do full justice to the subject, and I leave it with confidence in their hands.

Though as I stated the arrangements are simple, in my humble opinion they are far from complete. I will endeavor to give my reasons for thinking so. I told you ventilation may be performed either by abstracting the foul air and allowing the fresh to be supplied by gravitation, or by forcing pure air in, driving the foul air out; the arrangements on board the *Devastation* admit of either system being used simply by reversing the fans, but the latter, or forcing system is evidently intended to be chiefly relied upon, as no provision is made for the free introduction of fresh air by the first named process, except through the skylights

or hatchways, which more than likely have to be closed occasionally.

As the absence of special entrances for fresh air prevents the effective working of one system, so does the absence of special means of escape of foul air and gases, endanger the success of the other : in the one the foul air would of course be extracted, but in the other the fresh air on being forced into the room or compartment, would mix with the foul to a certain extent, especially as carbonic-acid gas settles towards the deck, where the mouths of the supply-pipes are placed. The theory that the air inside would be warmer and lighter, and thus pass upwards before the colder currents, I am afraid would not hold good here, for surrounded by so many tons of iron, I think it not at all unlikely that the outer atmosphere would be of a greater temperature, except perhaps in the vicinity of the engine department, and in that case no one could guarantee that the pure air would not pass out leaving the tainted behind, or at least mingling with it to such an extent as to render the quantity of fresh air necessary to be supplied considerably increased ; but to this there must be a limit, for the current would be so strong that it would be unpleasant, and perhaps dangerous to health.

I maintain that to ensure anything like perfect ventilation proper means should be provided for both sides of the operation, ingress, and egress ; the present system could be so adapted with comparatively little trouble, by taking one set of fans for forcing fresh air, and the other for abstracting foul. There are two main trunks already, except for the distance through the bunkers, where there is only one, but of course another could be added.

In support of this view of the question, I would suggest that it would be anything but pleasant or healthy to live surrounded by vitiated air, for though you may be sure you are receiving a certain amount of pure air when in your cabin or mess-room, you may be equally certain that outside, in the wings, passages, &c., you will encounter contributions from the many indescribable smells to be met with occasionally in the clean est ships. The downcast through the engine-room would no doubt take a great quantity of the expelled air in the vicinity of the gratings, but that would not affect to any extent the other parts of the ship. In this opinion I differ from the designers of this system, for the apertures over the engine-room are chiefly relied upon for the exit of expelled air from the greater part of the ship ; experience alone will decide this question, which in itself is not of any great importance ; it does not matter much which way the air is removed so that it is got rid of.

The small circular hatch over the ward-room is expected to perform the same office for the after part of the ship (a by no means extensive provision, and not a par ticularly palatable one either to those living in such close proximity to a point), towards which the currents of vitiated air from this part are to be driven.

I noticed there is no special ventilation for the series of w. c's urinals, they are open to the wing passage on the breastwork deck : they are close to the ports in the ship's side, but I think these will as often (certainly when to windward), let in air instead of allowing any escape, so that each time a door opens at the ends of the passage, there will be a rush of foul air into the whole after part of the ship. They should be enclosed, and provided with special means for ample ventilation, independent of any state of wind or weather.

The double-bottoms, as we are all aware, are apt to become the receptacle of dangerous gases, either evolved from the paint with which they are coated, from stagnant water, or if left open, from the setting by gravitation of the heavier gases given out by the many and various chemical actions continually going on in the ship.

To prevent accumulation to any dangerous extent, I would suggest, that periodically, and at no great intervals, they should be swept through by a current of air, either forced by ventilating engines, or if they are not at work, by opening all connecting sluice-valves and apertures at the extreme ends of the different series, and placing the centres in direct communication with the airing stoves in the engine-room or stoke-holes, so that the whole supply of air required for the stoves, should be drawn through the whole series of compartments. This would effectually prevent gas collecting, and in the event of an accident requiring men to enter the double-bottoms, there would be no delay. Even in harbor, when men are painting the double-bottoms, a ventilating fan has to be kept continually at work or the men would be suffocated. The man-hole doors are kept on at sea ; if this plan were adopted no inconvenience would be felt from the necessary practice.

Pipes are led from the double-bottoms to the upper deck, to allow the air to escape when water is being admitted to trim the ship; these pipes would serve either for the escape of air when forced in by the fans, or to supply a fresh stock to replace the amount removed by the stoves in the stoke-holes.

Official attention has of late been directed towards alleviating the sufferings of men employed in trimming coals, and arrangements more or less efficient have been introduced for supplying them with fresh and cool air. All those who have in the stern course of duty compassionated the men they were obliged to order into close hot bunkers to toil hard for four long hours, in an atmosphere thick enough to be cut, will hail these innovations with pleasure. It is difficult to appreciate the oppressive and stifling nature of the work performed by these best-abused and worst paid public servants.

Ventilating shafts are now being carried from the coal boxes into the funnel casing. the draught round the funnel causing a strong current of hot air from the upper parts of the bunkers; the supply of fresh air being admitted by the doors in the stoke-holes, which are generally situated in the vicinity of the main downcasts; this is certainly a step in the right direction, but much yet remains to be done to ensure anything approaching effective ventilation; however, we are thankful for the slightest indications of the introduction of a more considerate and liberal policy.

Up to the present time no provision is made in the *Devastation* for ventilating the coal boxes, but I have no doubt a subject of so much importance is only waiting its turn to receive the amount of attention it deserves. A portion of the air intended for the furnaces might be driven through the coal boxes. and the arrangement would afford a means for changing the air when not steaming, to prevent accumulation of gas, a very necessary precaution now that a percentage of north country coal is stowed. Several cases are on record of slight explosions having occurred, which might have originated serious fires.

Some of the more sanguine of our engineers and philanthropists point to the time when bone, muscle, and human life shall be greatly economized, by the introduction of mechanical stoking—may the time speedily arrive—at present, practical men do not see a clear way for the introduction of any such scheme, necessity in the shape of great scarcity in the coal supply, and its accompanying greatly enhanced price may, and most likely will solve the problem, or, a liberal encouragement offered by the government to our scientific men to bestir themselves, would undoubtedly answer the same purpose—it is simply a question of money; at present there is very little inducement for them to engage their time and capital in any such enterprise.

I will conclude with a remark or two upon the management of the ventilating apparatus—

The admission of air is optional in all cases, every supply-pipe being fitted with a stop-cock; the question arises, is it safe to leave it to the discretion of individuals or messes? I imagine it will often be a matter of keen dispute, tastes differ so much in these matters as well as in any other, and who is to decide? What guides are there to assist in regulating a proper supply—how far will temperature help to determine—or have we anything between shivering from excessive draught, and a depressing headache, coupled with a gradual extinguishing of the lights. I am unable to say what arrangements will be made; undoubtedly something clear and definite should be determined upon, and the whole placed under the supervision of a careful, intelligent officer.

IS 772 FOOT POUNDS THE TRUE DYNAMICAL EQUIVALENT OF ONE THERMAL UNIT.

By John Lowe, 1st. Asst. Eng'r. U. S. N.

Written for Van Nostrand's Magazine.

In order that we may easily understand the subject, let us suppose that we have a vessel of indefinite length, whose area is uniformly one square foot. Into this, place one cubic foot of boiling water. Now let us vaporize it.

The water will expand into steam and will occupy a greatly increased volume. This

expansion is resisted by a uniform pressure, for example, the pressure of the atmosphere.

The work then performed in overcoming this resistance, is a multiple of the resisting pressure (p), the area in inches of one square foot (144), and the ratio between the volume (V) of the steam and the volume (v) of the water; water at 39 deg. as usual being taken as unity. The work then is $W=p\left(\frac{V-1}{v}\right)144$

To perform this work heat has been applied which has not been manifested as sensible heat; so that the latent heat alone has performed this work. If then (Y) is the weight of the steam or of the cubic foot of boiling water vaporized, and if (L) is the number of thermal units latent in one pound by weight of steam, then (LY) is the total latent heat, and the dynamical equivalent (D) of one of these is $D=p\left(\frac{V-1}{v}\right)144$

L Y

If there is no fallacy in the foregoing, then the correctness of the formula depends upon the accuracy of the experiments of Regnault and others. If they are incorrect, then this formula is incorrect, but not otherwise.

Let us now give the quantities in the formula, different and corresponding values as in the table. We will find in the last column (D) the values for the dynamical equivalent under those conditions.

p	v	v	L	y	D
10	2373,	1,0359	978,99	60,282	55,85
14.61	1641,5	1,0426	965,7	59,838	57,511
20	1219.7	1,0492	954,38	59,459	58 85
30	826,32	1,0590	938,5	58,901	60,179
40	627,91	1,0668	926,42	58,481	62,47
50	508,29	1,0732	916,58	58,131	63,86
60	428,32	1,0789	908,18	57,817	65,169
70	371,07	1,0840	900,84	57,554	66,36
80	328,08	1,0884	894,27	57,322	67,28
90	294,61	1,0926	888,31	57,101	68,59
100	267,80	1,0964	882,35	56,891	69,74
120	227,56	1,1035	873,09	56,549	71,80

We find then that (D) is much smaller than generally supposed, and also that it is to all appearance a variable and not a constant quantity. The writer cannot explain the fact. For example, friction could not influence the result because it would be reproduced in heat. The only assignable reason is believed to be that the quantities derived from the perimeters above quoted are not rigidly correct. Several reasons might be given for this belief, but as the writer will be obliged to drop the subject for the present for want of time, it would perhaps be best not to advance these reasons until he can be assured of their correctness.

INDIAN HYDRAULIC CONTRIVANCES.

From "Engineering."

In India a large variety of mechanical contrivances of a very simple nature are commonly used for raising water from rivers or wells, or out of foundations of bridges, that are generally unknown to the English engineer. His natural tendency would be to use the appliances best known to him, such as a windlass and bucket, a common pump, a lift and force pump, or a winding-up chain carrying iron vessels; of these, the last only is very well known in India, in a more simple form, as a chain of pots, or a Persian wheel; pumps are purely European in origin, even a windlass is a comparative rarity, and since such things are not always available it often becomes necessary for him to adopt the native means of raising water and to learn what duty may be expected from them. To aid him, or rather to save him needless trouble in measuring and calculating the duty, the following Tables, based upon data originally furnished by M. Lamairesse, of Pondicherry, for Southern India, and in the Roorkee professional papers for Northern India, but modified and put in a form intelligible to the English civil engineer, may be found useful. It merely becomes necessary to explain the meaning of a few of the Indian names of the contrivances, and state the mode in which they are used.

Baling is one of the most primitive methods of raising water, but the English mode of filling and emptying a vessel or a bucket is not in vogue among the natives of India. A large flat dish of wood bark rendered water-tight, or leather stiffened by a frame, has two long cords attached to it at opposite sides, the other two ends of the cords being held by two men, who generally prefer sitting down to their

work, and together allow the dish to dip in the water, nearly fill itself, and then raise it, send it forward with a swing and let it empty itself above; this can be done with a rapid and continuous swinging motion that is sometimes quite surprising. This method is of course only applicable under certain conditions, such as clearing foundations of water, and such cases as allow of sufficient room for the swinging; the lift is seldom more than five feet though sometimes seven feet; but a series of such lifts can be easily adopted.

Machine.	Details.				Work Done.			Power Exerted.
	Lift in feet.	Men.	Oxen	Per Hour No of Lifts.	Cubic Feet Raised.		Gallons per Day of Eight Hours.	
					per lift.	per hour		foot-pounds per second.
1. Picotah...	10	2	...	600	.83	498	24,900	8 x10 = 80
2. "	20.5	2	...	300	1.44	432	21,600	6.9x20.5=141
3. "	20.5	2	...	240	1.60	384	19,200	6.2x20.5=127
4. Dal	10	6	...	1320	.33	443	22,150	7.1x10 = 71
5. Mot	11	...	2	44	1.77	78	3,900	1 3x11 = 14
6. "	20	...	2	90	2.00	180	9,000	2.9x20 = 58
7. "	45	...	2	32	1.75	56	2,800	0.9x45 = 40
8. Double mot	22.5	...	2	180	1.32	238	11,900	3.9x22.5= 87
					per min.			
9. Common pump ...	10	1	...	60	7.77	466	23,300	7.4x10 = 74
10. Mot	16	...	2	35	5.81	203	10,150	3.3x16 = 52
11. Baling	5	2	...	1200	.33	400	20,000	6.4x 5 = 32
12. Beam and bucket ...	16	1	...	180	.45	82	4,100	1.3x16 = 20
13. Windlass	4	1	...	84	2.00	168	8,400	2.7x 4 = 11
14. Dal	5	2	...	84	5.00	420	21,000	6.7x 5 = 33
15. Single mot	40	1	2	70	3.00	560	28,000	3 3x40 =132
16. Double mot	40	1	2	85	3.00	255	12,750	4.1x40 =164
17. Single chain of pots ...	40	1	2	168	.75	126	6.300	2.0x40 =160
18. Double chain of pots...	40	1	2	138	2.40	330	16,500	5.3x40 =212
19. Common pump ...	25	4	...	2400	.10	240	12,200	3.9x25 = 97
20. Lift and force pump ...	40	4	...	1440	.20	288	14,400	4.6x40 =184

The beam and bucket, or balance pole, in its various modifications, is also a favorite contrivance for raising water from wells by hand labor; the lever, at one end of which is hung the water vessel, generally a large earthenware pot, is counter-weighted at the other end so as just to allow the force of one man to raise the vessel when full. The lever is often a beam naturally very thick at one end, and requiring only to be carefully hung or supported at the most convenient point for a fulcrum. In Southern India this principle reaches its fullest development in the picotah; where a very large, long tree, or a very large pair of trees bound together, becomes the balance pole, to work which a man walks and runs backwards and forwards along the heavier arm of the lever, stepping off, when necessary, on to a raised stage; for this work special men thoroughly accustomed to it, are absolutely necessary; one managing the vessel, and the other the balancing. The size of these picotahs is sometimes extremely large, and the lift consequently very high.

The dal or jantu is a contrivance for raising water from three feet to six feet high by means of a wooden gutter moving on a pivot, being a lever, or a double lever of the second order; there are several forms of this contrivance; in the simplest, one end of the single gutter is raised by a man with a cord, or lever and cord, until the water runs out of the other end of the gutter into a trench; in the double gutter there is a wooden partition in the gutter immediately above the pivot, and the water runs out through holes on each side of it in the bottom of the gutter into the trench; sometimes these are worked by cords and sometimes by means of the weight of a man and a counterpoise weight at the end of a long lever attached.

The mot is an arrangement worked by oxen; it generally consists in a water vessel made of a complete ox-hide bound on to a wooden ring for an opening, raised and lowered by a cord running over a pulley, fixed immediately above or projecting over the well, the bullocks going down an inclined plane made for the purpose, when dragging up the water vessel or mot, which has to be dragged to one side on arrival above the mouth of the well and emptied by a man. In Southern India there is an improvement on this which dispenses wit

the man for emptying; the lower end of the mot tapers out to a good length, and has a smaller cord attached to it, which, by means of a suitably adjusted catch, causes the mot to empty itself on arriving at the proper height.

The contrivance generally called by Anglo-Indians a Persian wheel, but more properly a chain of pots, is almost identical with that used in Egypt, Nubia, Syria, Abyssinia, known there as the sakia; its advantage is that it will raise water from any depth by means of sufficient animal power. In India it is generally very much of the following description: Two parallel, endless ropes, united to each other by rungs of wood or of rope pass over a vertical wheel and hang down to below the water surface in the well; earthern or leathern vessels are attached to the rungs, which discharge themselves into a trough through the vertical wheel, which is a double framework. Motion is communicated to the axle of this vertical wheel from a vertical shaft of wood that is turned by a pair of bullocks, by means of two wooden wheels working into each other. The upper end of the vertical shaft is kept in position by a very heavy beam or tree, which rests also on two supports, generally mud walls, beyond the sweep of the circle in which the oxen walk. The principle of this rather rude but effective contrivance was doubtless the basis of the double iron chains of pots with brass buckets holding about a gallon each that were used by the Romans, and hence also the remote ancestor of our modern chains of pots having chains of jointed bar iron, skeleton six-spoked or hexagonal wheels, and buckets or iron casks of the most improved form; or, again, somewhat like those used on the Metropolitan District Railway to clear the line of water and worked by steam power.

Referring to the table given, the details of which have been reduced and modified in order to show as much as possible what comparison may be drawn in favor of each machine, it will be noticed that the full amount of work done and power exerted is there given for all cases, under a theoretical condition that never occurs in practice. In each and all of these machines a certain amount of work is wasted by leakage, spilling, faulty construction, or inexactness of form, delay for small repairs, and many other such causes. To obtain anything near the truth, therefore, a coefficient of reduction that is purely empirical must be applied. Some of these coefficients are given in the Roorkee professional papers, others are obtained from other sources; they may, for our purposes in dealing with such rough machines, be applied equally to the work done and the effective power exerted; but, as the latter is the principal object under consideration, we shall reduce the amounts under that head only, which become thus:

Number.	—	Coefficient of Reduction.	Effective Power in Foot-pounds per Second.	Number.	—	Coefficient of Reduction.	Effective Power in Foot-pounds per Second.
1	Picotahs ...	...	64	11	Baling	.75	24
2		.80	112	12	Beam & Bucket	.80	16
3		...	101	13	Windlass	.50	5
4	Dal	.70	50	14	Dal	.70	23
5	Mots ...	...	10	15	Mot	.70	92
6		.70	40	16	Double mot ...	.60	98
7		...	28	17	Single chain of pots	.55	89
8	Double Mot ...	.60	52	18	Double chain of pots.	.60	127
9	Common pump	.50	37	19	Common pump	.50	48
10	Mot	.70	36	20	Lift and force pump ...	.60	110

These results may not at first sight appear to admit of much comparison being made; certain things are, however, plainly indicated by them, the most marked one being that all such rough hydraulic contrivances used in small lifts involve a great waste of power as well as of water, much intermediate time being lost between the lifts, and the machine itself, when on a large scale, being more properly made and more carefully worked. This is shown most on comparing the effective results of the North Indian beam and bucket (12) with the Southern Indian picotahs (1, 2, 3); in the mots, on the other hand, the favor is on the side of the North Indian, probably from his using an additional man. The chain of pots more exclusively used in Northern India appears to be, under theoretical conditions, the most effective of all these contrivances; the data given is unfortunately too rough to draw any comparison between such contrivances and the common English pump. The foregoing figures may, however, be of use to those unacquainted with Indian contrivances when first called on to deal with them.

ON THE RECENT REACTION OF TASTE IN ENGLISH ARCHITECTURE.*

From "The Architect."

Whatever may be the opinion of those interested in architecture as to the wisdom of the reaction which is the subject of discussion in this conference to-day, there is sufficient evidence of the fact that there has been recently in England a reaction of taste against Gothic architecture towards what is commonly called Queen Anne architecture, a name which, though inadequate and unsatisfactory, is sufficiently intelligible.

But though this style of architecture is a form of classic, the question which engages us to-day is not the often-fought "Battle of the Styles," of which we are all weary. The issue under discussion is different. There is no question on either side as to whether the forms of architecture are to be bound down for ever to the same unalterable proportions, or as to whether we are to use a native style or one imported from Italy. Both those who favor the reaction and those opposed to it admit that Queen Anne architecture violates classic rules; and that it is of native growth as much as Gothic is.

Nor are the combatants the same as in the old well-fought battle of the styles. The peculiarity of the present movement is that the upholders of this form of classic are the same men who have hitherto been devotees of Gothic; who thought it, as I confess I used to think it, an abandonment of principle to use any other style, who practiced it in its severest forms, and even thought Chartres Cathedral a little too late; some of whom, acting as if they thought the monuments of English history ceased to be of value or interest after the sixteenth century, and, regardless even of what used to be thought the respect due to the memory of the dead, have helped to clear out of the old churches of England every vestige of what they considered debased Pagan taste with as much zeal as ever Puritan purged Church of idolatrous images. That these men should have been carried away by what Mr. Ruskin calls "the foul torrent of the Renaissance," and polluted themselves with what another writer calls "the abominations of Sir Christopher Wren," and fallen in love with a style which the upholders of classic and Gothic equally denounced as base, degenerate, and corrupt, seems to require some explanation.

Of the fact there can, I think, be no doubt. There has been an awakening in the minds of some men, who formerly cared nothing for any style but Gothic, to the interest and merit in Queen Anne architecture. One architect told me that, going back after a long absence to the office, where, full of youthful enthusiasm for Gothic, he had served his apprenticeship, he was astonished to find that it contained a most beautiful Georgian staircase, which he at once wished to measure, but which, though he had gone up it every day for five years, he had never before noticed. Another, not an architect, but interested in art, told me that he had lately ben surprised with the beauty of Hampton Court Palace, which on a former visit, some years before, he had found disappointing and uninteresting.

We see also buildings in this style, the work of architects brought up on Gothic.

Nor is the movement confined to architecture. The pre-Raphaelite school of painters have abandoned the purity and restraint with the stiffness and imperfection of Mediævalism, and glory in the fullness of physical life and the richness and freedom of classic ideas.

These are, I believe, true evidences of a reaction in taste. The rise in the price of Queen Anne furniture and chimney-pieces, pounds scarcely buying now what shillings bought a few years ago, is evidence merely that the movement has become fashionable, and consequently in danger of becoming vulgarized.

Some assert that the whole movement is a mere fashion, first started by Dante Rossetti, and imitated by his followers. As well say the Gothic revival was an imitation of Pugin or of Horace Walpole and his Strawberry Hill. Pioneers like these are not causes, but the first results of the causes which move the waves of the world's

*A paper read before the Society of Architects by MR. J. J. STEVENSON.

history. Their distinction lies in being taller than their fellows, and their eyes being the first to catch the beams of the new light that is rising.

In fact the architectural movement in each case is the sequence of a previous religious and literary movement.

As in the new light of French Revolution doctrines, the few vestiges of the Middle Ages which had survived the Renaissance, were passing away, the re-revived in the feeling of the time an appreciation of the glory and chivalry and adventure of the Middle Ages, of their religion also, and subsequently of their art.

In England this reaction to Middle Age ideas has strongly influenced the more imaginative minds; since the time of Sir Walter Scott their religion, poetry and art have been Mediæval. It was a natural and living movement, and for this very reason subject to the law of all living things, change, growth, and development. The feeling grew that there are elements of modern life which not Middle Age chivalry nor asceticism, nor Gothic architecture, were fitted to satisfy. The naturalism and emotionalism, the absence of restraint and conventionality, and also of refinement, began to pall, and men turned, as in the sixteenth century the generation trained in the same Mediæval ideas had turned, for satisfaction of the wants they felt rising in their nature to the treasures of classic literature, to the classic conception of life, glorying in full, healthy, natural outcome, yet moving in measured rhythm, and to the art which is the manifestation and expression of such life.

Minds which had passed through this process found in the forms of Renaissance art, produced under a similar process three centuries before, the expression of their own thoughts and feelings. Correct rigid classic art had no interest for them. They had still too much of the life and freedom of Gothic in their souls to submit to be bound down to ready-made lifeless rules. To classic art in them the infusion of the Gothic spirit gave—what the infusion of Gothic blood had given to the worn-out civilization of the later Roman Empire—new spirit and new life and the hope of higher development.

The springing up of a taste for some form of free classic architecture is therefore not unnatural, but was to be expected in those who had drunk deeply of Gothic. And the form of free classic which thus arose was naturally determined by local conditions. Englishmen working in brick, and using sliding sash windows according to the custom of the land (a custom the necessity of complying with which has ever been a thorn in the side of modern domestic Gothic), found the natural expression of their feelings in the brick architecture of the Restoration, of Queen Anne, and the Georges.

This architecture has neither the exquisite grace and refinement of Greek, nor the romance and high aspirations of Gothic, but it is perhaps not, therefore, the less suited for the common daily wants of English life. It has much to be said for it on practical grounds. Take the ordinary conditions of London building—stock bricks and sliding sash windows. A flat arch of red cut bricks is the cheapest mode of forming the window-head: the red color is naturally carried down the sides of the window, forming a frame; and is used also to emphasize the angles of the building. As the gables rise above the roofs it costs nothing, and gives interest and character to the building, to mould them into curves and sweeps. The appearance of wall surface carried over the openings, which, in Gothic, the tracery and iron bars and reflecting surface of thick stained glass had taught us to appreciate, is obtained by massive wooden frames and sash bars set, where the silly interference of the Building Act does not prevent, almost flush with the walls; while to the rooms inside these thick sash bars give a feeling of enclosure and comfort.

With these simple elements the style is complete, without any expenditure whatever on ornament. Some may say that it is not architecture at all, but mere building. As well say eloquence is impossible without sounding epithets and flowery paragraphs. Such simple building may test to the full an architect's highest faculties—the power of producing harmony and proportion—for there is nothing but harmony and proportion to depend on for the effect. We may, if we have money to spare, get horizontal division of the façade in this style, as in Gothic, by string courses and cornices, and we have the advantage over Gothic

that we can obtain vertical division by pilasters, which, though not constructive, any more than string courses as used in Modern Gothic, have at least as much meaning in a London house as pointed window arches.

Under other conditions some other form of free classic style would naturally prevail; as in Scotland, what is called "Baronial," which, while using classic details, is full of the spirit of Gothic; though the usual modern revival of the style, with its mimicry of fortification at the top and huge undivided plate glass windows at the ground level, expresses rather modern ostentation than the quiet reserved dignity of the old Scotch houses. In a stone country like Derbyshire the old local classic of the district with the windows divided by mullions and transoms is still suitable for modern wants; while in the more important buildings of our towns we may have a wide choice among the numerous forms of free early Renaissance. It is an abuse of words to call all these styles "Queen Anne." The term "Free Classic," or, if it is not a barbarism, "Re-renaissance," would more correctly designate the movement.

The style in all its forms has a merit of truthfulness; it is the outcome of our common modern wants picturesquely expressed. In its mode of working and details it is the common vernacular style in which the British workman has been apprenticed, with some new life from Gothic added. The great mass of dwelling-houses are built now, as in former days, without the aid of architects, and, as the builder, in his own work, is apt to imitate anything new which he sees architects have produced, there is some little hope of his carrying out this style without the painful blunders he, and some architects also, it must be confessed, make in attempting Gothic, of which they do not understand the grammar.

In truth the success of Gothic is with those who loved it one cause of this reaction. Its advocates urged that it was good not only for churches, but for every kind of building; that it ought to become again, as it had once been, the vernacular architecture of the country. The wish has been granted. The nineteenth century has expressed itself in Gothic; and, in gin-palaces, rows of houses built to sell, semi-detached villas, chapels and churches, Gothic, which of old was simple and unpretending, by means of its boasted freedom from restraint has lent itself with fatal facility to the expression of loudness, vulgarity, obtrusiveness, and sensationalism more objectionable far than the dreariest classic of Gower or Wimpole street. *That* may be very dull prose, the other is screeching sensational poetry or Daily Telegraphese.

The account which I have attempted to give of the genesis of the movement explains the fact that it has not extended to churches. In these, Gothic has not the practical difficulties which it encounters in house-building; and although as Dr. Newman says, the architecture of the Jesuit churches, with their untrammeled magnificence, is the true expression of Catholic feeling, Gothic architecture has for English churchmen the strong authority of old custom, and suits better their simpler ritual.

It explains also why those who have been affected by this movement would still design churches, and, if need were, other buildings also, in the Gothic style, which they have not ceased to understand and reverence, though it does not now, on all sides, bound their horizon.

It is much more important that our architecture should be good in whatever style is adopted than that it should be in any particular style.

Nor is it likely that the Queen Anne style in its old form should again become that of our London streets. It is cheering here and there to see old houses blossom out again in fresh red brick angles and white paint on the window frames, which, if done up a few years ago, would have been swathed in the dead-clothes of stucco. Tags and shreds of the style will doubtless appear in speculative builders' houses, and we may even see street rows in it, violating its best characteristic of freedom and spontaneity by repeating the same fantastic gable or the same elaborate porch as many times over as there are houses in the row. But the incompetent meddling of the London Building Act, and the sovereign will of the five or six great noblemen who dictate to Londoners the style of the houses they must live in, compel an autocratic monotony and forbid the characteristic features of the style,

with the picturesqueness and variety which make old towns so charming.

But one thing perhaps from this reaction we may hope for—that the wanton destruction of the old buildings of the style may cease; that the quaint spire of Hampstead Church may still be left to us—that the estate regulations which, on lease renewings, instead of freshening up the cheery old red brick and white window frames of the Bloomsbury houses, has been transforming them into vulgar dismal stucco, may be allowed to cease—that in the district farther west *all* the elegant old balcony railings and pretty wooden tracery of the lunettes above the doors may not give place to coarse cast-iron and plain sheets of glass. We may even, perhaps, see the plate glass removed again and the tracery and small panes restored. And I do not even despair that Mr. Burges himself, who alone almost of the champions of Gothic has been true to his first love for it, and has never fallen away to heathen abominations, may yet come to have such reverence and love for St. Paul's, not only as an historical monument, but as the great work of a great artist, as may make him feel it impossible for him to carry out his proposal of effacing and destroying Wren's design.

RIVER POLLUTION.

From "The Building News."

Mr. W. F. Butler, Assoc., Inst., C. E., read a paper "On the Reports of the Rivers' Pollution Commissioners," before the Civil and Mechanical Engineers' Society, in which he presented a great many items of interest to the sanitary engineer. The paper was exceedingly long, and we therefore cannot do more than give a few brief *excerpta* from it, premising that in it Mr Butler discussed the reports of the Commissioners on the pollution of the Aire and Calder. The important towns of Skipton, Keighley, Bradford, and Leeds, with a population of more than half a million, are situated in the basin of the Aire, while that of the Calder are Todmorden, Halifax, Huddersfield, Dewsbury, and Wakefield, which, with other smaller places, have a population nearly as large. According to the report, Skipton was rather in advance of some other towns in the basin, as the Local Board took every opportunity of substituting water-closets for privies. Some of the sewers of Keighley are described as being 3ft. high, 2ft. wide at the top, and 16in. at the bottom, and covered with flat covers, the only ventilation being by gullies at the street side. The Local Board of Keighley was opposed to the water-closet system, favoring the privy and ash-pit; nevertheless, it was found that sewers were not less necessary than in other towns, and that sewage required purification before being passed into rivers, whether water-closets passed human excreta into the sewers, or privies excluded the solids. At Keighley an instance is recorded in which there were four or five privies under one house, and a visitation of small-pox to the house killed seven out of its nine inhabitants. Bradford, which has a population of upwards of 100,000 inhabitants, is situated on both sides of a small stream called Bradford Beck, about four miles south of the Aire. Bradford Beck, with a drainage area of 14,660 acres, has been polluted to such an extent that to be "as foul as Bradford Beck" is locally tantamount to being more than usually filthy. The Beck receives the whole of the sewage of Bradford, and not only is the stream in great part covered over with buildings, but many proprietors on either side, claiming the soil to the centre of the beck, have placed the outer walls of their buildings in the centre of the stream, so that the water is divided, and (especially during floods) its flow seriously interfered with. Bradford had spent, at the date of the report, about £40,000 in constructing 10,720 yards of main sewers, being a first installment toward a complete system. The diameter of the main outfall sewer is 8ft. 6in., with a fall of 1. in 400, but this is intended to carry off storm waters, and, in fact, to act as a storm overflow, the actual outfall sewer being 4ft. 6in. in diameter, and its cost is stated to be £2 per lineal yard. The ventilation of sewers in Bradford was proposed to be by downspouts and ulti-

mately by chimney shafts, but the Commissioners pointed out that ventilation by downspouts could not be considered effective, as when most required—*i.e.*, during rainfall, the spouts would be charged with down-falling water; and in answer to the objection that open grids in the streets are unpleasant and even dangerous, they point to the fact that many hundreds of miles of London sewers are ventilated on this principle, and also to the known law that the dilution of foul gases is in proportion to the cube of space into which they are discharged. There is this o jection, however, to openings in the streets for sewer ventilation—viz., that in northern towns, where the cold is more intense than in London, they are liable to be covered with snow and frozen so as to become closed and useless. It is stated that ventilation by chimney shafts was found to render the air in the sewer sufficiently pure for a distance of 300ft. on either side of the place where the connection was made. At the date of the report there were in Bradford about 26,000 houses, with some 1,500 water-closets, and from 12,000 to 14,000 privies, with 6,000 ash-pits. For cleansing the privies and ash-pits the corporation paid about £2,700 per annum the refuse remaining the property of the contractor, who sold such portions as he could, and tipped the remainder into waste land, or used it to fill up holes, &c. Waterworks, giving a supply of 10,000,000 gallons per diem, had been carried out at a cost of three-quarters of a million. The last place of importance on the Aire, before its junction with the Calder, is Leeds, with a quarter of a million of inhabitants. At the date of the report, Leeds was only partially sewered and drained, but all the sewage from the drained parts of the town was turned into the Aire, as well as vast quantities of liquid refuse from all kinds of manufactures. The river below Leeds is described as so sickening to sight and smell that persons are advised to eat and drink before going near it. In addition to the liquid refuse, enormous quantities of solid refuse, such as engine ashes, house ashes, foundry dross, broken bricks, crockery, &c., were thrown into the river, so that the bed of the river was being gradually raised, to the great injury of surrounding property in time of floods. The principal pollution of the river Calder at Todmorden consisted of solid refuse, both manufacturing and domestic, which was continually cast in. Sewage pollution was not extensive, as the town had no regular system of sewers. Halifax, situated on the Hebble, a tributary of the Calder some miles below Todmorden, had been well sewered, the sewers discharging by one outlet into the Hebble. In size the sewers varied from a 9-inch pipe to stone sewers 5ft. by 3ft. 6in. The sewering of the town, coupled with good water supply, had mainly contributed to reduce the death-rate of Halifax from 34 to 24 per 1,000. Huddersfield, some distance to the south of the Calder, at the junction of the rivers Colne and Holme, was partially sewered and drained, the sewers discharging by five outlets, partly into the Colne and partly into the canal. Dewsbury, just below Huddersfield in the basin, and on the main stream of the Calder, was partially sewered with brick and stone sewers, discharging by six outlets into the river, and ventilated by manholes only. Wakefield, the last town of importance on the Calder, contributed to the contamination of the river by emptying therein not only its sewage, but dye-waste, soap-waste, and every possible kind of pollution, and yet the water supply of the town was mainly drawn from the river below the sewage outlet. The only town of importance on the united streams of the Aire and Calder is Pontefract, which was but partially sewered. The rivers and streams of Yorkshire in their natural state were described as being beautifully clear and pure, as might be inferred from a tradition that the women of Castleford, a town situated at the confluence of the Aire and Calder, were said to preserve their beauty by frequent use of the river water, or, as the old distich has it—

"Castleford lasses must needs be fair,
Washed in the Calder and bathed in the Aire."

The present condition of things is shown in the following lines, which though referring more particularly to Leeds, is more or less applicable to the whole of the towns on the Aire and Calder :—

"The Aire below is doubly dyed and damned;
The air above with lurid smoke is crammed.
The one flows steaming, foul as Charon's Styx;
Its poisonous vapors in the other mix.
These sable twins the murky town invest;
By them the skin's begrimed the lungs oppress'd.
How dear the penalty thus paid for wealth,
Obtained through wasted life and broken health."

An important item requiring the engin-

eer's strict attention and care, is the ventilation of sewers, and in this particular the towns in the Aire and Calder basin seem to be generally deficient. In many cases the rain-water pipes of houses form the only ventilators. The side entrances in some instances are relied upon, although in many cases they are covered with stones and road material. Neither downspouts nor manholes, even if the latter have the usual iron cover, can be considered efficient ventilators, the former being useless when most required, while the latter never allow a free flow of foul air unless the cover is raised. When sewers are not ventilated they transfer fever and other diseases from the lower to the higher parts of the town, as the gases constantly ascend to the highest end of the sewers; and in these cases the people who suffer most are usually those inhabiting houses of the better class, as in these the water-closet is almost universally adopted, and the foul gases are more intimately introduced into the house. As the Commissioners observe, the first requisite for sewering and draining is effectual ventilation, for if this be not attended to, sewering and draining a town may prove anything but a blessing; and they appear to consider that no better plan has been yet devised than that commonly followed in London. Some of the witnesses who were examined before the Commissioners advocated the use of factory or specially-built chimneys as ventilating shafts, and in one instance it was stated that this had been carried out with satisfactory results. But in the case of a system of sewers doubts were expressed as to whether the shafts would draw out the gases for any great distance on either side of the connection. In most cases special shafts would have to be built, for manufacturers would object to any air channels being carried into their chimneys, as each connection would diminish the draught. To ensure upward motion fires must be kept burning, and no air should reach the fire save from the sewers. No reliance could be placed on the unventilated water-trap to prevent foul gases from entering houses. The water would become surcharged with gas, and the gas would be transmitted almost as though there were no intervening water. The unventilated water-trap was a delusion and a snare. Mr. Butler then discussed at some length the fiercely-contested question of "Water-closet *v.* Privy," coming to the conclusion that generally the water-closet was the cleanest, cheapest, and most effectual means that could be devised for the rapid removal of human excreta. The earth-closet system was of course to be preferred to the privy and cesspit, but the water-closet was the only known contrivance which was applicable to large centres of population. Having dealt with the pollution of the Aire and Calder by manufacturing refuse, and shown that it was not only necessary but possible that much, if not all of this refuse, might be purified before being passed into our water courses, Mr. Butler remarked that the common law with regard to river pollution seemed to be that no person or corporation could acquire a right to create a public nuisance, but the persons or corporations could acquire prescriptive rights, by user of twenty years, to pollute streams and occasion nuisances which, while not injurious to health, might cause injury and annoyance to other individuals, so long as a public nuisance was not created. Of course, any person creating a nuisance was open to an action within the twenty years by those who were injured; but this was a very unsatisfactory and expensive process, and uncertain in its results, since the whole proceedings might be upset on some legal quibble having nothing whatever to do with the merits of the case. Besides, neighbors did not like going to law with one another, as it caused ill will and bad feeling, and cases frequently occurred in which persons sold mills and other property rather than quarrel with their neighbors. All this pointed to the urgent need of comprehensive legislation upon the important subject of river pollution. An important aspect of the question was the effect of river pollution upon health. Almost all the towns named in the report on the Aire and Calder exhibited an extremely high death-rate. At Wakefield it was 27.41 per thousand; at Huddersfield, 24.90; at Leeds, 33.80; at Bradford, 28.00; at Skipton, 26.00; at Castleford, 18.00 to 23.00; and at Pontefract, 29.10 As stated in the former paper on the Thames and Lea, it was difficult to trace disease directly to polluted rivers; they caused a general lowering of health among people living near them, rather than any direct sickness. At the same time there were certain types of disease which were seldom absent from their neighborhood. Typhus and typhoid fever

and small-pox were nearly always present, while cholera was ever ready to attack a population already enfeebled by foul air, bad water, damp subsoil, and ill-ventilated and overcrowded dwellings, and so predisposed to its terrible influence. In conclusion, Mr. Butler dealt with the rainfall and water supply of the Aire and Calder district.

WHITWORTH STEEL.

From "Iron."

Sir Joseph Whitworth has lately published an account of his method of casting and rifling steel guns (*Guns and Steel.* By Sir Joseph Whitworth, Bart. London: Longmans & Co.). He states that from the first he was impressed with the superiority of steel as a material for guns, although for a considerable period the difficulty of obtaining that metal in a state sufficiently ductile and at the same time free from air cavities stood in the way. Highly carbonized steel, when cast in small ingots, comes out sound in the greater portion of its bulk; but in larger castings, owing to the irregular cooling and unyielding character of the material, it is liable to crack or become unsound. Experience has, in fact, shown that it is impossible to cast a large gun of highly carbonized steel that can be relied upon as perfectly sound. With a small amount of carbon in its composition, however, steel becomes so ductile that it will elongate under pressure from 30 to 35 per cent. before breaking, and then will not fly in pieces, but only bulge and tear. But again, steel of this description has the defect of being subject to honeycomb during the casting process, owing to the presence of air cells. To obviate this, recourse was had to the application of extreme pressure to the metal, while in the fluid state, a pressure in some cases of as much as twenty tons on the square inch. As a measure of the quantity of air expelled by this process, and the consequent improvement in density and soundness, it is stated, within five minutes after the application of pressure the fluid column will be shortened by an inch and a-half per foot of length, and drawing out and forging develops in a still higher degree the strength of the material. The importance of this invention, not alone to weapons of war, but also to the still more useful implements of peace, need not be dwelt upon. In the single article of railway axles, the failure of which is such a fruitful source of accidents, it must be invaluable. In the construction of steam-boilers, also, the fluid-compressed steel may be substituted for the material at present in use, with the very best results, both in increased efficiency and a diminished liability to collapse.

The gun steel is cast in hollow cylinders, for obvious reasons connected with rapid cooling and more complete exclusion of air, and Sir Joseph gives a very interesting account of the experiments by which, by means of gunpowder, their powers of resistance was tested. A crucial test was the explosion of 1½lb. of R. L G. gunpowder in a cylinder made of Whitworth fluid-compressed steel, with no other escape for the gas generated than a vent one-tenth of an inch in diameter. "The cylinder was a copy of the breech end of a 9-pounder Whitworth muzzle-loading gun, cut off at the trunnion with the projectile screwed in. It is estimated that the consequent strain would be six times greater than that produced if the shot were free to leave the gun. When fired, it recoiled thirty-two inches along the sand, from the rush of gas through the vent, although the weight was 467 lbs. The screw plug was then taken out, and the cylinder was measured both externally and internally, but no alteration had taken place. The vent, however, had been enlarged in diameter, by the rush of gas from one-tenth to two-tenths of an inch." Sir Joseph refers, with evident soreness, to a report by General Lefroy, in his capacity of professional adviser to the Secretary of War, on a similar experiment, in which that official stated that he thought it "not improbable that good cast iron would stand the test shown." This is a good example of the trials which beset an inventor's path, and it is of importance to remark that owing to the incompetence or prejudice of this individual, the conversion of cast iron guns was persevered in after the superiority of the new material had been satisfactorily demonstrated. The Whitworth ductile steel is manufactured in

thirteen qualities, ranging from a tensile strength of forty tons per square inch to one of seventy-two, the ductility at the two extremes, being respectively thirty-two and fourteen per cent.

In 1854, Sir Joseph was called in to assist Lord Hardinge in his endeavors to obtain the best possible rifle with which to arm the British troops. A series of experiments was accordingly commenced, the track of the bullet being traced throughout its entire course and the trajectory recorded, the first result being the construction of the Whitworth small-bore rifle. Sir Joseph commenced a new series of similar experiments in the following year, restricted in this case to the regulation weight of bullet and charge of powder, but unrestricted in every other particular. The barrel of the Whitworth rifle, as here described by its inventor, is thirty-nine inches in length, the interior is hexagonal in section, and, instead of consisting, as in the Enfield, of non-effective bands and partly of grooves, has rifling surfaces which are wholly effective. The rifling turn is much quicker than that of the Enfield rifle, being one turn in twenty inches, and the angular corners of the hexagon are rounded.

The maximum diameter of the bore is .490 of an inch, and the minimum diameter is .451 of an inch. The bullet may be either hexagon or cylindrical; in the latter case it will expand and be drawn into the recesses of the hexagon, and will adapt itself to the curves of the spiral rifle; in the former case, the inclined sides of the hexagon offer no direct resistance to this expansion, which is easily effected. The length of the bullet is three diameters of the bore. The hexagon form of the rifling has several auxiliary advantages. It allows, for example, of the use of a mechanical-fitting bullet of any degree of hardness, even of steel, an advantage obtained under no other mode. Again, however, obstructions were placed in the way by obtuse officials, a committee of officers reporting to the Government that the bore of the Whitworth rifle was too small for use as a military weapon. Ten years afterwards a similarly constituted committee reported to the War Office that the calibre of a breech-loading rifle should be .45 inches, the exact bore recommended by Sir Joseph Whitworth ten years previously, and another committee of officers, at an intermediate period, reported "that the makers of every small-bore rifle having any pretensions to accuracy have copied to the letter the three main elements of success adopted by Mr. Whitworth—viz., diameter of bore, degree of spiral, and large proportion of rifling surface."

Sir Joseph predicts that, as regards heavy artillery, the professional advisers of the Crown will probably require some time before they are able to see that sound ductile steel is the best material for a gun, that the bore for a given height should be made smaller than at present, that the projectile should be lengthened and its rotation increased. "Following past precedent," however, he anticipates that when the improved methods he advocates make due impression on the official mind they will be adopted, his part in first developing them being at the same time forgotten.

For artillery it is of the highest importance to use that form of projectile which is best fitted for penetration. This, as appears from the result of a great many experiments, is the flat-headed form. Shell or shot of this shape are not deflected in passing through water—a most important property when it is considered that armor-plated ships are easily vulnerable below the water-line. The power of penetration of a steel projectile of this shape is prodigious, a 70 pounder muzzle-loading gun, sending such a shot through a four-inch iron plate and nine inches of oak at 200 yards. In the experiments with Whitworth guns of seven-inch and $5\frac{1}{2}$ inch bores at Shoeburyness, against three iron plates, respectively $4\frac{1}{2}$ and five inches thick, backed with eighteen inches of teak, and having an external skin of iron made of $\frac{5}{8}$-inch plate, the whole forming an imitation of a portion of the side of the *Warrior* ironclad, the projectiles, which were steel shells three diameters in length, flat-headed, and fired point blank at 800 yards, penetrated in three out of four trials, through the five-inch plates, and burst in the timber backing. Still more important is the power possessed by flat-headed projectiles of piercing armor-plates at extreme angles, for in actual warfare the projectile rarely impinges on an armor-plate perpendicular to its surface. The smashing effect of a flat-headed projectile is also much greater than that produced by a pointed one. All this is, however, trifling to the effect produced by the larger guns. "In March, 1870, a

nine-inch armor shell, 3½ diameters long, and made of fluid-compressed steel, was fired at a distance of 200 yards, against the War Office shield. The shell weighed 404 lbs., its length was 31½ inches, and the powder-charge was 50 lbs. The shield was composed of three five-inch plates, interlaminated with two five-inch layers of iron concrete, the whole forming a mass twenty-five inches thick. The penetration was 25½ inches, a portion of the rear end of the shell, measuring six inches, was left protruding, but perfect, neither broken nor upset ; but remained a most striking illustration, which has never been equalled, of the power of the nine-inch Whitworth gun." Sir Joseph discusses next, at some length, certain subsidiary questions of detail, such as the length of projectiles, the weight to powder-charge, the influence of the length of the gun and of rigidity in the carriage, compares the advantages and disadvantages of his hexagonal shot with the studded projectiles of Palliser, shows the superior economy also of his own method, and concludes with a description of the nine-pounder breech-loading gun and carriage exhibited at South Kensington, in 1872, and of which a public trial was made at Southport, in the same year.

The following challenge was placed upon the gun :

"This gun will be fired on the sands at Southport, Lancashire. the latter end of September. Messrs. Joseph Whitworth and Co. will be glad to compete with any British or foreign gun and carriage of the same weight, for range, accuracy, penetration, and rapidity of firing."

This gun is made of fluid compressed steel, and the breech is closed by a heavy sliding block of the same material, working between two portions of the breech end of the gun, under and over the sliding block, which may be called block guides. The faces of the block guides are grooved with a number of parallel grooves, the upper and lower surfaces of the block being similarly formed, and inclined at a very small angle to a plane perpendicular to the axis of the gun, thus forming a portion of a screw thread, which would be traced upon a cylinder of extremely large radius. These threads constitute what may be called a "straight-line screw," having their sides nearest the muzzle undercut, so that when the heavy strain, resulting from firing the charge comes upon the block, there may be no tendency to force the block guides apart; but, on the contrary, they are more tightly held. The powder chamber is enlarged in diameter and reduced in length, being 2¼ diameters long, and containing a charge of fifty per cent. more powder than the service charge of a muzzle-loader. There is also a slightly enlarged shot chamber to ensure ease in loading. The enlargement of the shot chamber permits of the reduction of the windage in a degree which could not otherwise be attained. In this gun the enlargement is .03 of an inch, the remaining part of the bore having windage .01 of an inch.

The sliding breech block is shaped at the side, so as to form a part of a tube of the same diameter as the powder chamber; the hollowed-out side of the block forms a prolongation of the powder chamber when the breech is open.

For the convenience of loading it is desirable to fit an inner guide into the tubular part, corresponding with the bore of the piece, and similarly rifled, and through this rifled guide piece the projectile passed into the shot chamber. The guide piece is not, however, absolutely necessary, as the gun can be loaded without it, and in all cases it is removed before the powder cartridge is inserted. The breech block is movable horizontally, and the small obliquity of the threads causes it to tighten itself with sufficient force against the rear end of the gun. It is readily moved to and fro, and provides a large amount of bearing surface for resisting the explosion ; the bearing surface in this gun being 30.24 inches, which is three times greater than that which supports the vent piece in the service breech-loader of the same calibre. The breech block is worked by means of a rack and pinion, a stud being formed on the back of the breech block, and a weighted hand lever being mounted upon it ; on the same stud a pinion is mounted, which gears with a rack fixed upon the lower guide of the breech block. The pinion is worked by the hand lever, the handle and pinion have interlocking projections, allowing, however, the handle some freedom of motion, so that it may be used with a hammer-like action to start the breech block.

The mechanical features of the breech-loader may be recapitulated briefly as follows :

1. A heavy breech piece with a large area of bearing surface.
2. An enlarged diameter of powder chamber.
3. A slightly enlarged shot chamber.
4. A diminished windage in the bore of the gun.

The carriage like the gun is made of "fluid-compressed steel," and has the trail formed by side plates connected at the rear ends by a metal shoe, and at intervals by cross pieces or stays. The bearings in which the trunnion arms rest, are forged solid with the side plates. The axle passes through the side plates immediately beneath the trunnion of the gun, and through a flanged tube, which is fitted and bolted between the side plates, and forms the main stay. The ends of the axle are coned to receive the wheels, which are bushed with brass, and on each end of the axle a screw thread is cut ; a nut on this thread, when screwed up binds the wheel tightly between two collars upon the axle, and resists by friction the tendency of the wheels to revolve when the gun recoils on firing. The screws on the axle are right and left handed, whereby the recoil tends to tighten the nuts.

In order to elevate the gun, a forked lever is jointed to the side plates, just below the axle, and this lever at its rear end, carries a trunnion nut, in which a hand-screw works. The screw is carried by a collar provided with studs or trunnions on either side, which are received into a cross piece connecting the two side plates, and secured there by a cap. The forked lever is connected with the breech end of the gun by a rod, which is pin-jointed, both to the lever and to the gun. The

connecting rod has two or more pin-holes in it, and by shifting the pin connecting the rod with the lever from one hole to another, an increased range of elevation is obtained. On either side of the gun metal ammunition boxes are hung, the axle passing through the middle of the box.

By this construction of carriage the gun is brought down very close to the axle, and consequently less strain is thrown upon the frame, the recoil taking place nearly in a straight line.

BAIE VERTE CANAL.

Written for Van Nostrand's Magazine, by THOS. GUERIN.

The government of the Dominion of Canada has in contemplation the construction of a canal through that isthmus which connects New Brunswick and Nova Scotia, a distance of some 20 miles, so as to connect the navigation of the Bay of Fundy with that of the Gulf of St. Lawrence at a place called Baie Verte.

Different engineers, under the authority of the government, have made surveys, and each has devised a different plan which is recommended as being the best to render the canal successful in its functions when completed.

It is admitted that to accommodate the amount of traffic that will be required of this canal, a daily consumption of 12,000,000 cubic feet of water will be required for navigation purposes; and there being no means in the adjoining locality of producing this amount, it is decided that the canal must be so constructed as to make the tides of the Bay of Fundy available for the required supply.

According to tidal observations which were continued at the Bay of Fundy from the middle of the month of August, 1870, to that of January 1871, the datum having been so assumed that the mean level of the sea stood at 71.40 feet, the tides in the Bay of Fundy varied between 85 and 96 feet; while at Baie Verte, from the month of August, 1870, to the month of May, 1871, the tides varied between 71.60 feet and 77.90 feet.

The government within the last two years has published several reports on the proposed construction of this canal; principal among which are two—one of these I shall designate by K; the other by P.

The report K proposes to construct a canal which shall have a high-water surface at an elevation of 92 feet above datum, and low water at 86 feet; thus giving a depth of 6 feet for storing a supply by which to work the canal—the bottom level is to be at an elevation of 70 feet above datum. The canal is to be 100 feet wide at bottom, the slopes 2 to 1: it is to be 16 feet deep—locks 40 by 270 feet; length of summit-reach 12½ miles; length of second reach 7.7 miles.

This plan proposes to fill the summit reach to a level of 92 feet above datum, from the tides of the Bay of Fundy, and by means of those tides and a small lake in the interior, to maintain that level, or prevent the surface from descending below a level of 86 feet.

The plan P has its high-water surface at a level of 88 feet above datum; low water at 85 feet; thus giving a depth of 3 feet for storing a supply. The length of the summit reach is 18½ miles; the bottom level is at an elevation of 69 feet.

To provide for additional storage, plan P proposes to excavate two reservoirs near the terminus at the Bay of Fundy, which we shall designate by A and M.

Reservoir A is to have a surface area of 5,915,000 square feet, and a length of 9,200 feet. Reservoir M is to have an area of 4,775,000 square feet and a length of 21,800 feet.

A channel 260 feet wide and one foot below low-water line of canal will connect each reservoir with the Bay. In each channel a bulk-head is to be constructed with such a number of openings as will in the aggregate in each case make 250 feet in width for the admission of the tide when it rises to the level of low water or 85 feet above datum.

A channel 100 feet wide and 2 feet below low-water line is to connect each reservoir with the canal, and the water is to be delivered over weirs from these two channels into the canal.

It appears to me that questions arise in reference to this proposed canal which have never before occurred in engineering.

In the present case it is necessary that the high and low-water surfaces and the bottom of the canal must be at such eleva-

tions, and the dimensions must be of such magnitude, as to enable the tide to fill the canal to the required level within a reasonable time. It will be necessary to empty the canal occasionally for the purpose of cleaning; and there must be means at hand to fill it speedily again and to maintain its surface at the required level for the purpose of navigation.

The time required to fill a canal or reservoir to a certain height must depend on the elevation of the bottom and on the velocity with which the tide flows into it.

No comparison can be made between the velocity of the tide at sea and its velocity flowing up the bed of a river or through a channel. The horizontal velocity of the tidal wave in the Pacific Ocean is stated to be 1,000 miles an hour and in the Atlantic ocean 700 miles an hour, and yet the depth of the moving tide is insignificant, the tidal wave being only $2\frac{1}{2}$ to 3 feet high.

The general direction of the tidal wave is from east to west, and yet on land it is seen at various places to move from west to east. The Gulf of St. Lawrence and the Bay of Fundy are on the east and west sides of the isthmus through which the proposed canal is to be constructed; they are only about 20 miles apart in this locality; and yet I can bear testimony to the fact, that thetide runs to the east up the beds of streams which empty into the Bay of Fundy, while it runs to the west at the same time from the Gulf of St. Lawrence up the bed of the river Tidnish. It is true that the high water is earlier at the east side of the isthmus than at the west side by about 2h. 30m.; but it takes some six hours to rise, and hence during the remaining 3h. 30m. the tide is running in opposite directions.

From these facts it would be erroneous to suppose that the velocity of the tide at sea is a function of the velocity with which it moves up the bed of a river. The inland velocity of the tide must therefore depend upon the head or height to which the waters are piled on the adjacent lands which obstruct it in its course from the sea; and hence the vertical and horizontal velocity of the tides must be co-ordinates of one another.

Let r = the height to which the tide rises in seconds of time t.

v = the mean horizontal velocity durring the same time.

Then vt = the horizontal distance advanced.

$\frac{r}{vt}$ = the tangent of inclination of the thread of the current thus generated.

The inclination of a current always varies as the square of the velocity, unless the velocity is very small; the section and wetted perimeter being constant. In the present case it is the velocity of the advancing fillet we are in search of. Its section and wetted perimeter are always the same, while the width of the bed is the same—hence $\frac{r}{vt} \propto v^2$; and if t is constant or equal to one hour $r \propto v^3$; hence $v = n \sqrt[3]{r}$ where n is a coefficient which I have determined in the following manner:

There is the bed of a small stream called the river Missiguash, in the vicinity of the proposed canal, at a distance of about $1\frac{1}{2}$ miles from the seashore. On a calm day I caused a length of 4,148 feet to be measured along the bank of this river, and further on, another distance of 13,040 feet was measured along its bank in the same direction. I caused the flowing tide to be watched, and the time to be noted during which the advancing fillet was traversing those latter two distances. The time occupied in the first case was 25 minutes, and in the other 1h. 20m.; thus giving a velocity in the former case of 2.76 feet per second, and in the latter of 2.717 feet. I caused the height to which the tide had risen during those two times to be noted by means of gauges. In the first case it amounted to about 3.87 feet; in the second case it amounted to about 11.30 feet; thus r in the one case is nearly 9.30 feet and in the other about 8.50 feet. The cubic roots of these numbers are nearly in the ratio of 2.76 to 2.717; a fact which goes to corroborate the theory first established.

Hence

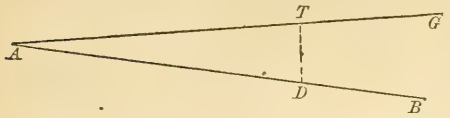
$$\frac{2,717}{\sqrt[3]{8.50}} = n = 1.3313$$

This is an important principle and worthy the attention of engineers who may be engaged on similar duties. It is to be hoped that some gentleman will verify or amend this coefficient in some other locality.

It may perhaps be objected that the value of n, thus obtained from the movement of the tide up the bed of a river or inclined plane, will be inapplicable in de-

termining the velocity, while moving along the bed of a horizontal canal.

FIG. 1.

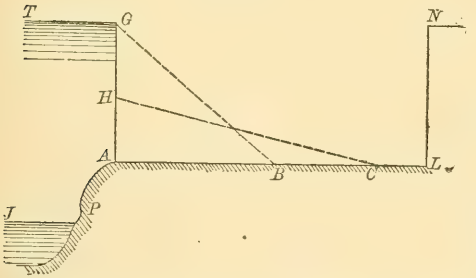


Let A B represent the bed of the canal; A G that of the river; suppose A D to be the velocity along A B, D T being drawn perpendicular, A T will represent the velocity in ascending A G. That is to say; if radius represent the velocity of the tide in moving in the horizontal bed, the cosine of the inclination will represent the velocity up an inclined plane.

I have ascertained the inclination of the bed of the Missiguash by taking cross sections in a few places, and connecting those levels with the datum of the survey. The inclination thus obtained gives an angle whose tangent = .00076.

This angle is so small that the cosine may be considered equal to the radius; hence there is no difference between the velocity of the tide moving up the bed of the river Missiguash, and that of the same tide moving in the horizontal bed of a canal.

FIG. 2.



Let us now return to the subject of filling a canal or reservoir from tide water.

Let A L N G be the summit reach of the canal or reservoir, and A C the entrance gate through which the tide water is admitted: J P being the level of ebb or low tide, and T G that of flood or high tide.

Let us suppose that while the tide was rising the distance A G, it advanced in the canal the distance A B: then the surface of the water, at the end of the first tide will be indicated by the line G B.

While the tide is at the level T G, or high ide, the gate A G is closed, and the water will commence to descend from G, and advance beyond B. Let us suppose that, during a given time, it has fallen the distance G H, and advanced the distance B C; then the line G B will conform to H C.

Let x = G H and y = B C;

t = Time in seconds of falling the distance x, or advancing distance y;

v = horizontal velocity of tide when it acquires the position A G B, and

v' = when it acquires the position A H C;

v'' = mean velocity while advancing along B C;

$v'' = \frac{v+v'}{2}$

a = A G = the distance the tide has risen from the moment it commences to enter the canal until it reaches flood or high tide;

b = A B = horizontal distance advanced. in the same time.

Now

$$v : v' :: \sqrt{\frac{a}{b}} : \sqrt{\frac{a-x}{b+y}} \text{ and } v' = v\sqrt{\frac{ab-bx}{ab+ay}}$$

$$v'' = \frac{v}{2} + \frac{v'}{2}\sqrt{\frac{ab-bx}{ab+ay}}$$

and multiplying by t we get

$$\frac{tv}{2} + \frac{tv'}{2}\sqrt{\frac{ab\ \ bx}{ab+ay}} = y \ldots\ldots\ldots [1].$$

Again, let w = width of canal at bottom;

n = ratio of side slopes;

a = depth, as before.

Then the quantity of water received by the summit-reach from one tide will be

$$\left(\frac{a\,w}{2} + \frac{a^2\,n}{3}\right) \times b$$

When G shall have descended to H (Fig. 2): then a becomes $a-x$, and b becomes $b-y$. We then have

$$\left(\frac{w}{2} + \frac{a\,n}{3}\right) a\,b = \left(\frac{w}{2} + \frac{a-x}{3} \times n\right)(a-x)(b+y \quad [2].$$

From these two equations, when any one of the quantities x, y, t is given, the other two can be found.

Considering the movement of the tide within the summit-reach of the canal, it is manifest that, when the reach is long, as in the present instance, the quantity of water poured into it by one tide, cannot have come to a level before the next succeeding tide commences to enter the canal.

Let us suppose that H, Fig. 2, is the point where the next tide commences to enter; then the time occupied in flowing into the canal is limited to the time the tide takes to rise the distance H G.

Let g = entire rise of tide = distance J T; or difference of level between high and low tide;

c = mean vertical velocity of tide per second, during ebb and flood.

Then $\frac{2g-x}{c}$ = time elapsed from previous high tide until the water commences again to enter the canal = t in seconds.

Equation 1 now becomes

$$\frac{(2g-x)v}{2c} \times \left(1 + \sqrt{\frac{ab-bx}{ab+ay}}\right) = y \ldots . [1_a].$$

From equations $1a$ and 2 we obtain x and y. We are thus enabled to ascertain the elevation at which every tide commences to enter the summit-reach; also the distance each tide has advanced, and the distance fallen from H towards A before the next succeeding tide or third tide commences to enter, etc.

It must be observed that w represents the width of opening of the canal, always at the level of the point H. It is only at the entrance of the first tide that w will represent the width of the bottom of the canal—similarly, a will represent the distance A G only at the first tide; it will represent H G afterwards.

Applying the above formulas to the plan K, I find that without using any water for navigation, the canal could not be filled to an elevation of 92 feet by the tides of the Bay of Fundy, from August, 1870, to January, 1871.

Let us admit that the summit-reach of the canal, according to plan P, is filled up to the required elevation of 88 feet above datum, having 3 feet in depth of water stored in the canal and reservoirs, thus holding a quantity of 81,000,000 cubic feet in reserve to be used as required; let us see whether the canal will remain navigable or preserve its lower elevation of 85 feet and at the same time afford 12,000,000 cubic feet per diem, or 6,000,000 cubic feet between each tide for navigation purposes. The canal and reservoirs have a horizontal area of 27,000,000 square feet.

Let us take the month of October, 1870, and admit that on the 12th day of that month the canal and reservoirs were full to the required level of 88 feet above datum; and that each 12 hours 6,000,000 cubic feet were drawn for navigation. Let us take advantage of every tide, and accordingly find the value of x, from equations 1^a and 2.

I shall admit that, during three tides, the volume supplied by the first of the three had come to a level in the reservoirs before the third tide entered; a circumstance which is not strictly the case; and has a tendency to show that the head, and consequently the volume of water, flowing into the reservoirs, are greater than they really are; thus representing the level of the canal above its actual elevation. However, I concede this allowance, because the calculations that would be required to ascertain the quantity fallen until the entrance of the third tide, etc., are long and tedious, and my time is limited, but the question of the efficacy of the reservoirs shall be fully settled, although conceding to them those advantages.

In the annexed table, the elevations above datums of the tides of the Bay of Fundy are given as they had been registered each day. The tides which occurred at night are intercalated.

The letters A and M refer to the reservoirs already referred to. The rest of the table explains itself.

It may be seen that on October, 19th, the elevation of the surface of the canal would be such that it could not afford the necessary quantity for navigation, and on the day following it sinks below the required level.

Table showing the elevation of Reservoirs A. and M. at the moment of entrance of each tide: also the elevation of the canal at the same time.

October 1870.	Elevation of Tide.	Elevation of Reservoirs at moment of entrance of Tide.		Values of X.		Elevation of Canal.
		A.	M.	A.	M.	
12	89.95	88.000	88.000	....	....	88.000
13	88.95	87.778	87.778	....	....	87.778
13	88.65	87.718	87.719	1.050	1.049	87.596
14	88.40	87.489	87.489	.844	.844	87.491
14	88.10	87.290	87.290	.825	.825	87.304
15	87.40	87.069	87.069	.735	.735	86.994
15	86.70	86.791	86.791	.314	.314	86.774
16	86.00	86.552	86.552	....	....	86.552
16	85.50	86.330	86.330	....	....	86.330
17	85.00	86.108	86.108	....	....	86.108
17	85.00	85.885	85.885	....	....	85.885
18	85.30	85.663	85.673	....	....	85.663
18	85.70	85.441	85.441	....	....	85.441
19	86.00	85.234	85.234	.246	.246	85.221
18	86.20	85.077	85.077	.697	.697	85.019*
20	86.40	84.929	84.928	1.009	1.008	84.815
20	87.10	....	....	....	....	.....
21	87.80	....	....	....	....	.....
21	88.80	....	....	....	....	.....

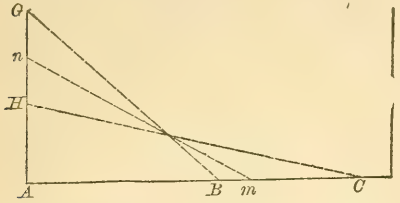
In calculating the quantities in the above table it may be remembered that I have

*Here the supply fails to be effective, and will continue to fail for several tides.

taken the mean velocity while moving over y, equal to an arithmetical mean between the velocity v and v' at the commencement and end of y.

Although this appears quite reasonable, yet let us ascertain the actual value of this mean velocity.

FIG. 3.



Let A C be the bottom of the canal or reservoir, and A G the gate, as before.

Let r = mean vertical velocity in falling the distance G H or x;

z = mean horizontal velocity in moving over B C or y:

t = time in seconds of describing x or y:

G $n = dx$, and B $m = dy$:

v = velocity at B, as before.

Then we get

$v\sqrt{\frac{a-dx}{b+dy}}\times\frac{b}{a}=$ velocity at the point m, and this may be considered the velocity with which dy is described. Hence

$dt\,v\sqrt{\frac{a-dx}{b+dy}}\times\frac{b}{a}=dy=z\,dt$, and

$v\sqrt{\frac{a-dx}{b+dy}}\times\frac{b}{y}=z$. Hence

$tv\sqrt{\frac{a-dx}{b+dy}}\times\frac{b}{a}=y$ and

$a\,b\,t^2\,v^2-b\,t^2\,v^2\,dx=a\,b\,y^2+a\,y^2\,dy$.

Substitute the value of dx, and there results

$a\,b\,t^2\,x^2-b\,v^2\,t^2\,r\,dt=a\,b\,y^2+a\,y^2\,dy$.

Integrate—substitute $t^2\,z^2$ for y^2, divide by t^2, and substitute x for $r\,t$, there results

$$z=v\sqrt{\frac{b}{a}\left(\frac{a-\frac{1}{3}x}{b+\frac{1}{3}y}\right)}$$

In the calculations above referred to, v'' gives a larger value for the mean velocity than z: consequently the efficiency of the reservoirs will be worse than it is represented in the above table.

Using the value of z, instead of v'', the forgoing equations become

$$tv\sqrt{\frac{b}{a}\left(\frac{a-\frac{1}{3}x}{b+\frac{1}{3}y}\right)}=y\ldots\ldots\ldots\text{N° 1}$$

$$\frac{2g-x}{c}\sqrt{\frac{b}{a}\left(\frac{a-\frac{1}{3}x}{b+\frac{1}{3}y}\right)}=y\ldots\ldots\ldots\text{N° 1a}$$

$$\left(\frac{v}{2}+\frac{an}{3}\right)ab=\left(\frac{v}{2}+\frac{a-x}{3}\times n\right)\times\sqrt{a-n}\times\sqrt{b+y}\ldots\ldots\ldots\text{N° 2}$$

THE CALCULATION OF STRAINS IN TRUSSES WITH INCLINED AND CURVED CHORDS, BY MEANS OF DIAGRAMS.

By E SHERMAN GOULD, C. E.

Written for Van Nostrand's Engineering Magazine.

In trusses with horizontal chords, all strains are transmitted to the abutments through the web members alone, but in the case of such trusses as roof principals, bow-string girders, etc., the chords, being inclined, sustain a portion of the vertical strains, which they convey to the abutments. The calculation of this class of trusses becomes, therefore, more complicated than that of the horizontal systems, and the simplest and surest method of solving their strains is probably that of *dingraming*, that is by the graphic application of the resolution of forces. A certain amount of practice is necessary to enable the student to obtain accurate results by the graphic process of calculation, but when the principle of the method is understood, and the proper degree of manual dexterity acquired, he will find himself in command of resources which permit him to approach all problems of bridge-strains with a confidence that no purely analytical method can give. No mistake is possible, except through carelessness; every force is represented on his draft, in direction and magnitude, and its pathway through the various members of his structure clearly indicated. There are no formulas to remember, and no tables to consult: a scale, straight-edge, triangle, pencil, and a sheet of drawing paper are all that are necessary to solve the most intricate problem which can present itself.

At first it might appear that this method was deficient in accuracy. The student will soon perceive that a slight change in the position of his straight-edge will often produce a difference of several tons in the

strain upon certain members of his structure, and if he is working on a long and complicated truss, he will find it impossible to draft the strains twice alike, the differences being greater or less according to his skill in handling his instruments. He may be tempted therefore to fear that he is employing very clumsy means to arrive at results requiring great accuracy, and be ready to resign the graphic method for any other which promises more mathematical certainty. A little consideration, however, will convince him that this seeming defect is in reality one of the greatest recommendations of the system. The changes of strain which the slightest deviation in the lines of his draft bring about, will reveal to him what is likely to occur in the actual structure, and teach him one of the most important lessons of practical mechanics, namely, the impossibility of reducing static strains to a mathematical certainty. Mons. Claudel, one of the first French authorities on construction, says in his "Pratique de l'art de Construire," in speaking of de-centreing arches—"no "matter how well the equilibrium may have "been calculated, no matter with what "pains all the properties of the materials, "all imaginable accidents, may have been "studied, we may rest assured that at the "moment of abandoning an arch to itself, "the forces of nature will establish a dif-"ferent equilibrium from that calculated "upon, although it may very nearly ap-"proach it, and in many cases differ only "in a degree quite inappreciable to our "senses." If this be true of an arch of masonry, each voussoir of which has been exactly dressed to the templets, and which is subjected only to the gradually applied strain of a permanent weight, to how much greater an extent will it hold good of a structure like a railroad bridge, over which a constantly varying load is drawn at a speed of 20 or even more feet per second? It is probable, in view of unavoidable imperfections of workmanship, the difficulty of keeping all the members of a bridge in actual bearing, and the manner in which a portion—often the greater portion—of the load is suddenly applied and withdrawn, that the roughest draft, in which any pretension is made to preserve the given dimensions, approaches more nearly the theoretical lines of pressure, than do the strains which actually find their way through the structure when it is doing its regular work. I do not wish to be understood as advocating therefore, slovenly and careless work—that would be only making confusion worse confounded—but I do wish to strongly impress upon the student that the strict results which a careful calculation gives him, are only true so long as every member of his truss is in perfect bearing, and *only* in bearing, and so long as the line of pressure passes through the centre of the joints. These are conditions never realized in practice, and considerable allowance must be made, particularly in bow-strings, for variation in the lines of pressure from causes which cannot be reckoned up.

I will now give a few examples of the method of working out strains by means of diagrams, in the hope of inducing students to perfect themselves in this very valuable and useful method. In drawing the diagrams the larger the scale the better, consistently with keeping the draft within reasonable limits. The following examples have been mostly worked out on a scale of five feet to the inch, and five tons to the inch.

These scales are amply sufficient in most cases, and are frequently larger that can be conveniently employed.

FIG. 1.

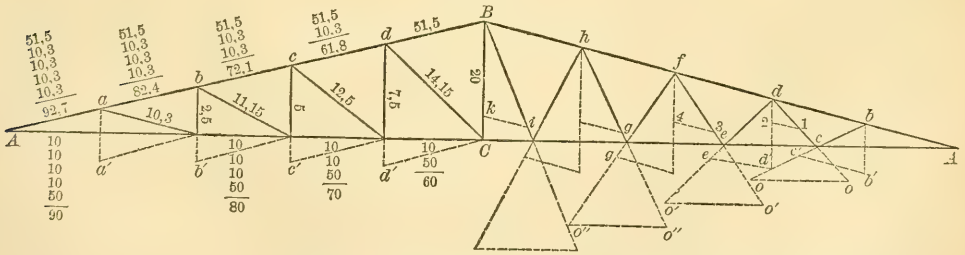


Fig. 1 is a roof principal with a horizontal bottom chord. The span is 100 feet rise, 12.5. It sustains a permanent and equally distributed load, equivalent to five tons on each apex of the bracing. The left hand half represents a system of verti-

cal ties and diagonal struts; the right hand, a system in which both ties and struts are inclined. In the left hand figure, the end panels of the lower chor are 20 feet in length, and the rest 10 feet each. In the right hand figure, the end panels are 15 feet, and the rest 10. In both figures, the upper chord is divided in equal panel lengths.

Let us first take the left hand figure, as the simplest. Mr. Stoney's method of diagraming roofs, is to take the reaction of the abutment and work it along to the centre, adding the different weights as they occur. This method always gives correct results; is applicable to all cases, and should be resorted to when there is the least uncertainty respecting the strains. It has the practical disadvantage, however, of carrying the total strains through the whole calculation, and the strain-lines get very long and inconvenient. Other methods may frequently be employed which give the strains in detail, the totals being obtained by addition. These methods permit the use of a much larger scale for the strains, and are generally of a handier application. We shall work out the present example in the following way. Apex a bears a weight of five tons. This weight is sustained by diagonal a and Aa. Draw $aa' =$ five tons. From a' draw a line parallel to AB. Its intersection with diagonal a (or a produced,) gives the strain on diagonal $a =$ 10.30 tons, and an equal strain on Aa. Both of these strains are compressive. The foot of a resting on the lower chord gives a vertical strain $=$ 2.5 tons on vertical b, and a horizontal strain $=$ 10 tons through the first panel length of the lower chord. These strains are tensile. The vertical tie transmits its strain to apex b, where it is augmented by the weight of five tons resting on b. Total, 7.5 tons, which draw to scale in bb'. This strain is sustained by diagonal b and Ab. From b' draw a line parallel to AB intersecting diagonal b. This shows a compressive strain of 11.15 tons on b, and one of 10.30 tons on Ab. This must be added to the 10.30 tons already on Aa, making so far, a strain of 20.60 tons on Aa. Diagonal b gives a vertical tensile strain $=$ five tons on vertical c, and a horizontal tension $=$ 10 tons on the second panel length of the lower chord. This, added to the 10 tons already on the first panel, gives so far a strain of 20 tons upon that panel. Proceeding in the same manner, we get compressive strains on diagonals c and d of 12.50 and 14.15 tons respectively, and increments of 10.30 tons each for upper panel lengths cb and cd. Tension of 7.5 tons on vertical d, and increments of 10 tons each on the 3d and 4th lower panel lengths. Arriving at the centre, we find a tensile strain of 10 tons on vertical B, which must be doubled, since it receives the same from the strut on the other side. It now remains to determine the compression in upper panel length dB, and the tension in the corresponding lower panel length. Diagonal d transmits, as we have seen, 10 tons to apex B. The weight of B transmits its half, or 2.5 tons to the left abutment, through AB. The total strain traveling through AB is therefore 12 50 tons. Draw BC 12.50 tons. The strain in $AB =$ 51.5 tons and in AC, 50 tons. Adding the compressive strains already found, we have, in Bd, 51.5 tons; in dc, 61.8 tons; in cb, 72.1 tons; in ba, 82.4 tons, and in aA, 92.70 tons. In like manner we have, in the corresponding lower panel lengths, $50+10 = 60$ tons; 70 tons; 80 tons and 90 tons.

In the above example the scale and dimensions are such, that the strains happen to be represented by the lengths of the members themselves; that is, the strain throughout AB is represented by AB itself, that in AC by AC itself, the strains in the diagonals by their own lengths, and the strain in each vertical by the length of the vertical preceding it. The panel increments are also represented by the panel lengths.

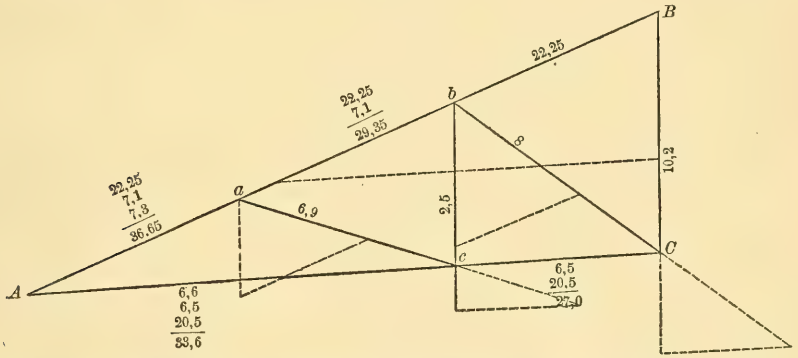
The right hand side of the figure shows the half of a truss of the same dimensions and loading, but with a different system of bracing. It is rather more complicated, but admits of a neat solution. From b, draw $bb' =$5 tons. This weight is borne by panel length Ab and strut bc. Draw $b'c'$ parallel to AB. The strain on Ab is represented by $b'c' =$67 tons, and that on bc by $bc' =$7.3 tons. From c, draw co (on bc produced) $= bc' =$7.3 tons. Draw oo parallel to Ac. Produce dc till it intersects oo. Then $co =$4.8 tons $=$ tension on dc, and $oo =$10 tons tension in cA from weight on b. From d, on dc, draw $d1 =$ 4.8 tons, and from 1 draw 1.2, parallel to AB, intersecting a perpendicular dropped from d. Then 1,2=3.5 tons=strain (compression) on db from tie dc, and $d2$=2.5 tons=vertical strain of same tie on db and

de. There is also a weight of 5 tons on *d*, which lay off from $2=2d'$. From *d'*, draw *d'e'* parallel to *AB*, intersecting *de* produced. Then $d'e'=6.2$ tons=compression in *db* from vertical strain above mentioned, and $de'=8.5$ tons=compression on strut *de*.

NOTE.—This construction may puzzle the student for a moment, for it may appear as if the strain on *db* from tie *dc*, was taken twice. If however he lays off, as before, $d1=4.8$ tons, and from *d* lays off 5 tons on the perpendicular dd', and takes the resultant of those two forces, and then resolves them along *db* and *de*, he will obtain the result already found. The method I have used makes the action of the last tie *Bi* rather plainer than when the forces are combined, as just described, which is my reason for employing it.

From *e*, lay off $eo'=de'$, draw $o'o'$ parallel to *AC*, produce *fe* to *oo'*, then $eo'=$ 7.2 tons=tension on *fe*, and $o'o'=10$ tons=tension on *ec* from weights on *d* and *b*. Proceeding thus, we get 10.4 tons and 12.5 tons compression on struts *fg* and *hi*, and 9.7 tons and 12 tons tension on ties *hg* and *Bi*, with increments of 10 tons and 10.2 tons compression through *fd* and *hf*, and increments of 10 each through corresponding panels of lower chord. The vertical strain on *B* from tie $Bi=10$ tons, and half the weight on $B=2.5$ tons, also passes through *BA* to the right abutment. Total 12.5 tons, which lay off in *BC*, obtaining compression=51.5 tons through *AB*, and 50 tons tension through *AC*. But *AB* sustains also 4.6 tons from tie *Bi*, making total strain of 56.1 tons. Adding the increments together we get finally compressions of 56.1 tons; 66.35 tons; 76.35 tons; 86 tons, and 92.7 tons respectively in *Bh*, *hf*, *fd*, *db* and *bA*, and tensions of 50 tons, 60 tons, 70 tons, 80 tons and 90 tons in the lower chord panels.

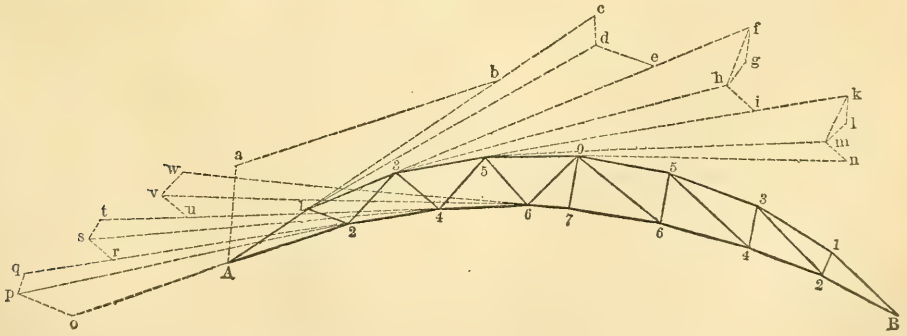
FIG. 2.



When the lower chord is inclined, the same method is applicable. Fig. 2 shows half of a roof principal in which the upper chord or rafter has a rise of 1 in 2.25, and the lower chord, or main tie, a rise of 1 in 15. Each apex being supposed to sustain a weight of five tons, the strains in every member are shown on the figure.

In the very graceful "bent girders" of which Mr. Stoney gives examples on pages 127 and 130 of his first volume, the system of calculation which we have been using is no longer applicable. The strains must be worked out from the reaction of the abutments. As this style of girder offers a good example of the method mentioned, I will give the full work in the case of a roof principal, Fig. 3, 80 feet span, rise of top

FIG. 3.



chord 16 feet ditto, bottom 10 feet. The radius of the upper chord=85 feet, that of the lower, 58 feet. The figure shows two different systems of bracing; let us first consider that shown in the left hand half. The upper chord is divided into equal panels; in the lower chord all the panels are equal except the first, which are $1\frac{1}{2}$ times the length of the others. The load is supposed to be of 8 tons which is equivalent to 1 ton per apex. Half of the entire weight, *i.e.* 4 tons, is borne by each abutment, but in our calculations we count only 3.5 tons as the reaction of the abutment, that is, half the weight on the apexes only, for the other ton being borne by the abutments directly, is immediately annulled, and need not be taken into the account.

The process of calculation is as follows: draw Aa perpendicular to the line joining the ends of the truss,=3.5 tons. Draw ab parallel to $A2$, and produce $A1$ till the two lines intersect. The reaction of the abutment Aa is thus resolved into its components through $A1$ and $A2$, and gives the strain Ab=12.3 tons=compression in $A1$, and ab=10.4 tons,=tension in $A2$. From apex 1, take $1c$ on Ab produced=12.3 tons, and from c draw cd perpendicularly, =1 ton=weight on apex 1. Then $1d$ = resultant of this weight and the strain in $A1$, which passes through 1, 2 and 1, 3. Produce 1, 3 in $1,f$, and draw de parallel to 1.2. till it intersects $1,f$ in e. Then $1.e$= 13.5 tons=compression in 1.3, and de= 2.4 tons=tension in 1.2.

NOTE.—Care must be taken in these diagrams to distinguish between compressive and tensile strains. The direction of the force, or of the resultant of the forces, furnishes the necessary indication. Thus, the resultant $1d$, passing *outside* of the two members 1, 3 and 1, 2, and acting in the direction of their opening, exerts compression on the member (1,2) nearest to it, and tension on that (1,2) farthest from it. It acts precisely like a weight suspended from a crane, compressing the *jib* (1,3) and drawing the *tie* (1,2). If acting in the contrary direction, *i. e.* towards the abutment A, the resultant would exercise contrary strains on the two members. Did the resultant pass *between* the two members, acting toward their opening, it would compress them both, and if acting in the contrary direction, would strain them both in tension.

From 2, lay off 2, o on $A2$ produced= 10.4 tons, and from o draw op=2.4 tons, parallel to 1,2. Then $2p$ is the resultant of forces in $A2$, and 1.2 acting in tension on 2, 4 and 2, 3. Draw pq parallel to 2,3 and produce 2, 4 till it intersects with pq at q. Then $2,q$=11.7 tons=tension in 2,4, and pq=1.05 ton=tension in 2,3. On 1,3 produced, lay off $3f$=1, e=13.5 tons; from f draw perpendicular fg=1 ton=weight on apex 3, and from g draw gh parallel to 2,3 =1.05 ton. Then $3h$ is the resultant of the strain in 1,3, the weight on apex 3, and the strain on 2,3, which all meet at apex 3. This final resultant is resolved into its components in 3, 5 and 3, 4, by drawing hi parallel to 3, 4 and producing 3, 5 to the point of intersection i. Then $3i$=13.1 tons =compression in 3, 5, and hi=1.36 ton= tension in 3, 4. The tension in 4, 6= 12.2 tons, and that in 4,5=0.91 ton is then found as before, and the compression in 5.0=12.9 tons, and tension in 5.6=1.04 tons. Finally, the tensions in 6, 7=12.2 tons, and in $6,o$=1 ton are found, as before. In practice it is unnecessary to actually draw the lines representing the resultants.

The strains in the members of a principal, trussed as shown in the right hand half of the figure, are solved in the same manner. In this system, the diagonals act as struts, and sustain compression. Under the same loading as assumed for the preceding case, we have compressions of 13.7 tons; 12.7 tons; 12.6 tons, and 12.6 tons on $B1$; 1,3; 3, 5, and 5,0 respectively; compressions of 0.6 tons; 0.45 tons, and 0.2 tons on 2, 3, 4,5, and 6,0 respectively; tensions of 11.8 tons; 12.3 tons: 12.6 tons, and 12.7 tons on $B2$; 2, 4; 4,6, and 6,7 respectively; and tensions of 1.75 tons; 1.65 tons; 1.7 tons, and 1.4 tons, on 1,2; 3,4; 5,6, and 0.7 respectively.

It will be noticed that in these and the preceding examples, the strains in the top chord, diminish from the abutments towards the centre, and those in the bracing augment in the same direction, contrary to what obtains in straight girders. This is because a part of the shearing strain passes through the chords, when inclined, instead of being transmitted wholly through the bracing, as is the case when they are horizontal.

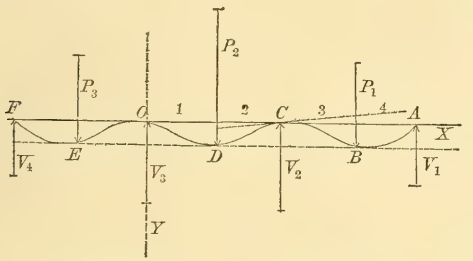
THEORETIC DISCUSSION OF TWO EXPERIMENTS ON THE DEFLECTION OF BEAMS.

By H. T. EDDY, C. E., Ph. D., Cincinnati, O.

Upon page 370, Vol. VII. of this magazine are the results of two "Experiments on the Deflection of Continuous Beams Supported at Equidistant Points," it being a paper read before the American Society of Civil Engineers, by J. B. Francis,

C. E. It is proposed in this article to discuss the theory of a beam supported at three equidistant points, and to show that the results of the above-mentioned experiments agree much more closely with Navier's theory of flexure than the remarks of the experimenter would lead us to suppose.

The beams experimented on were wrought iron bars 12 feet $2\frac{3}{4}$ inches long, supported upon 4 knife edges placed 4 feet asunder and in the same horizontal line. They were loaded at the points midway between the points of support, the weight $P_2 = 82.84$ lbs. being at the centre of the middle span, and the weight $P_1 = 52$ lbs., being at the centre of the end spans in each case, when it was found that the deflection of the middle span differed from the mean deflection of the end spans only .001 inches, *i. e.* the deflection of the middle and end spans may be considered to be equal.



Let the figure be an exaggerated representation of the neutral axis of the beam, take OX and OY as axes (y being positive downwards).

Let OC = CA = $2a$ and let P = weight of the beam per inch of length.

Take the moments of the forces acting about any point in curve (1) or OD.

$$\therefore \text{E I } \frac{d^2y}{dx^2} = P_1(3a-x) + P_2(a-x) + \frac{p}{2}(4a-x)^2 - V_1(4a-x) - V_2(2a-x) \ldots\ldots (a_1)$$

Take the moments about any point in curve (2), or DC.

$$\therefore \text{E I } \frac{d^2y}{dx^2} = P_1(3a-x) + \frac{p}{2}(4a-x)^2 - V_1(4a-x) - V_2(2a-x) \ldots . (a_2)$$

Take the moments about any point in curve (3), or C B.

$$\therefore \text{E I } \frac{d^2y}{dx^2} = P_1(3a-x) + \frac{p}{2}(4a-x)^2 - V_1(4a-x) \ldots\ldots\ldots (a_3)$$

Take the moments about every point in curve (4), or B A.

$$\therefore \text{E I } \frac{d^2y}{dx^2} = \frac{p}{2}(4a-x)^2 - V_1(4a-x) \ldots (a^4)$$

Integrate (a_1) between the limits: $x = a$ and $x = x$. If $x = a$ (*i. e.* at the point D, which is the centre point of the middle span), the tangent to the neutral axis must be horizontal, because the weights and supports are symmetrically situated with respect to it.

$$\therefore \frac{dy}{dx} = 0 \text{ at D.}$$

$$\therefore \text{E I } \frac{dy}{dx} = P_1\left[3ax - \frac{x^2}{2} - \frac{5a^2x}{2}\right] + P_2\left[ax - \frac{x^2}{2} - \frac{a^2}{2}\right] + p\left[16a^2x - 4ax^2 + \frac{x^3}{3} - \frac{37a^3}{3}\right] - V_1\left[4ax - \frac{x^2}{2} - \frac{7a^2}{2}\right] - V^2\left[2ax - \frac{x^2}{2} - \frac{3a^2}{2}\right] \ldots\ldots (b_1)$$

Integrate (b_1) from $x = 0$ to $x = x$. When $x = 0$, then $y = 0$.

$$\therefore \text{E I } y = P_1\left[\frac{3ax^2}{2} - \frac{x^3}{6} - \frac{5a^2x}{2}\right] + P_2\left[\frac{ax^2}{2} - \frac{x^3}{6} - \frac{a^2x}{2}\right] + \frac{p}{2}\left[8a^2x^2 - \frac{4ax^3}{3} + \frac{x^4}{12} - \frac{37a^3x}{3}\right] - V_1\left[2ax^2 - \frac{x^3}{6} - \frac{3a^2x}{2}\right] \ldots . (c_1).$$

Take (c_1) at the point D, when $x = a$, and call the deflection under P_2, y_2 *i.e.*, let $x = a$ and $y = y_2$

$$\therefore \text{E I } y = -\frac{a^3}{6}\left[7P_1 + P_2 + \frac{67}{4}pa - 10V_1 - 4V_2\right] \ldots\ldots\ldots (c_1).$$

Integrate (a_2) from $x = a$ to $x = x$.

When $x = a$, then $\frac{dy}{dx} = 0$.

$$\therefore \text{E I } \frac{dy}{dx} = P_1\left[3ax - \frac{x^2}{2} - \frac{5a^2}{2}\right] + \frac{p}{2}\left[16a^2x - 4ax^2 + \frac{x^3}{3} - \frac{37a^3}{3}\right] - V_1\left[4ax - \frac{x^2}{2} - \frac{7a^2}{2}\right] + V_2\left[2ax - \frac{x^2}{2} - \frac{3a^2}{2}\right] \ldots . (b_2).$$

At the point C the tangent to the curve is not horizontal, as is assumed by the experimenter.

$$\therefore \text{ let } \frac{dy}{dx} = t_c \text{ at C where } x = 2a, \text{ then } (b_2) \text{ becomes}$$

$$\text{E I } t_c = \frac{a^2}{2}\left[3P_1 + \frac{19}{3}pa - 5V_1 - V_2\right] \ldots . (b_2)'.$$

Again, integrate (b_2) from $x = 2\,a$ to $x = x$. When $x = 2\,a$, then $y = 0$.

$$\therefore \text{E I } y = \text{P}_1\left[\frac{3\,a\,x^2}{2} - \frac{x^3}{6} - \frac{5\,a^2x}{3} + \frac{a^3}{3}\right]$$
$$+\frac{p}{2}\left[8\,a^2x^2 - \frac{4\,a\,x^3}{3} + \frac{x^4}{12} - \frac{37\,a^3x}{2} + 2\,a^4\right]$$
$$- \text{V}_1\left[2\,a\,x^2 - \frac{x^3}{6} - \frac{7\,a^2x}{2} + \frac{a^3}{3}\right]$$
$$- \text{V}_2\left[a\,x^2 - \frac{x^3}{6} - \frac{3\,a^2x}{2} + \frac{a^3}{3}\right] \ldots\ (c_2).$$

Take (c_2) at the point D, thus $x = a$ and $y = y_2$.

$$\therefore \text{E I } y_2 = -\frac{a^3}{6}\left[5\,\text{P}_2 + \frac{43}{4}p\,a\right.$$
$$\left. - 8\,\text{V}_1 - 2\,\text{V}_2\right] \ldots\ldots\ (c_2)'.$$

Integrate (a_3) from $x = 2\,a$ to $x = x$. When $x = 2\,a$, then $\frac{dy}{dx} = t_c$

$$\therefore \text{E I}\left[\frac{dy}{dx} - t_c\right] = \text{P}_1\left[3\,a\,x - \frac{x^2}{2} - 4\,a^2\right]$$
$$+\frac{p}{2}\left[16\,a^2x - 4\,a\,x^2 + \frac{x^3}{3} - \frac{56\,a^3}{3}\right]$$
$$- \text{V}_1\left[4\,a\,x - \frac{x^2}{2} - 6\,a^2\right]$$

Add to this $(b_2)'$

$$\therefore \text{E I } \frac{dy}{dx} = \text{P}_1\left[3\,a\,x - \frac{x^2}{2} - \frac{5\,a^2}{2}\right]$$
$$+\frac{p}{2}\left[16\,a^2x - 4\,a\,x^2 + \frac{x^3}{3} - \frac{37\,a^3}{3}\right]$$
$$-\text{V}_1\left[4\,ax - \frac{x^2}{2} - \frac{7\,a^2}{2}\right] - \text{V}_2\,\frac{a^2}{2} \ldots\ (b_3).$$

Take (b_3) at B when $x = 3\,a$ and let $\frac{dy}{dx} = t_b$

$$\therefore \text{E I } t_b =$$
$$\frac{a^2}{2}\left[4\,\text{P}_1 + \frac{26}{3}\,p\,a - 8\,\text{V}_1 - \text{V}_2\right] \ldots\ (b_3)'$$

Integrate (b_3) from $x = 2\,a$ to $x = x$. When $x = 2\,a$, then $y = 0$.

$$\therefore \text{E I } y = \text{P}_1\left[\frac{3\,a\,x^2}{2} - \frac{x^3}{6} - \frac{5\,a^2x}{2} + \frac{a^3}{3}\right]$$
$$+\frac{p}{2}\left[8\,a^2x^2 - \frac{4\,a\,x^3}{3} + \frac{x^4}{12} - \frac{37a^3x}{3} + 2\,a^4\right]$$
$$- \text{V}_1\left[2\,a\,x^2 - \frac{x^3}{6} - \frac{7a^2x}{2} + \frac{a^3}{3}\right]$$
$$- \text{V}_2\left[\frac{a^2x}{2} - a^3\right] \ldots\ldots\ (c_3).$$

Take (c_3) at B when $x = 3\,a$, and $y = y_1$, say,

$$\therefore \text{E I } y_1 = \frac{a^3}{6}\left[11\,\text{P}_1 + \frac{93}{4}pa\right.$$
$$\left. - 20\,\text{V}_1 - 3\,\text{V}_2\right] \ldots\ldots\ (c_3)'.$$

Integrate (a_4) from $x = 3\,a$ to $x = x$. When $x = 3\,a$ then $\frac{dy}{dx} = t_b$

$$\therefore \text{E I}\left[\frac{dy}{dx} - t_b\right] = \frac{p}{2}\left[16\,a^2x - 4\,a\,x^2 + \right.$$
$$\left.\frac{x^3}{3} - 21\,a^3\right] - \text{V}_1\left[4\,a\,x - \frac{x^2}{2} - \frac{15\,a^2}{2}\right]$$

Add to this $(b_3)'$

$$\therefore \text{E I } \frac{dy}{dx} = 2\,\text{P}_1\,a^2 + \frac{p}{2}\left[16\,a^2x - 4ax^2\right.$$
$$\left. + \frac{x^3}{3} - \frac{37\,a^3}{3}\right] - \text{V}_1\left[4\,ax - \frac{x^2}{2} - \frac{7\,a^2}{2}\right]$$
$$- \text{V}_2\,\frac{a^2}{2} \ldots\ldots\ (b_4).$$

Integrate (b_4) from $x = 4\,a$ to $x = x$. When $x = 4\,a$ then $y = 0$.

$$\therefore \text{E I } y = 2\,\text{P}_1\,a^2\left[x - 4a\right]$$
$$+\frac{p}{2}\left[8a^2x^2 - \frac{4ax^3}{3} + \frac{x^4}{12} - \frac{37\,a^3x}{3} - \frac{44\,a^4}{3}\right]$$
$$- \text{V}_1\left[2\,ax^2 - \frac{x^3}{6} - \frac{7\,a^2x}{2} - \frac{22\,a^3}{3}\right]$$
$$- \text{V}_2\left[\frac{a^2x}{2} - 2\,a^2\right] \ldots\ldots\ (c_4).$$

Take (c_4) at B when $x = 3\,a$ and $y = y$.

$$\therefore \text{E I } y_1 = -\frac{a^3}{6}\left[12\,\text{P}_1 + \frac{107}{4}\,p\,a\right.$$
$$\left. - 26\,\text{V}_1 - 3\,\text{V}_2\right] \ldots\ldots\ (c_4)'$$

Subtract $(c_1)'$ from $(c_2)'$

$$\therefore 2\,\text{P}_1 + \text{P}_2 + 6\,pa - 2\,\text{V}_1 - 2\,\text{V}_2 = 0 \ldots\ (d)$$

also subtract $(c_3)'$ from $(c_4)'$

$$\therefore 23\,\text{P}_1 + 50\,p\,a - 46\,\text{V}_1 - 6\,\text{V}_2 = 0 \ldots\ (e)$$

The experiment was so conducted that $y_2 = y_1$.

Then subtract $(c_4)'$ from $(c_2)'$

$$\therefore 7\,\text{P}_1 + 16\,p\,a - 18\,\text{V}_1 - \text{V}_2 = 0 \ldots\ (f)$$

From (e) and (f) by elimination

$$62\,\text{V}_1 = 19\,\text{P}_1 + 46\,p\,a \ldots\ (h)$$

and $62\,\text{V}_2 = 92\,\text{P}_1 + 164\,p\,a \ldots\ (k)$

Substitute these in (d)

$$\therefore \frac{\text{P}_2}{\text{P}_1} = \frac{49}{31} + \frac{24\,p\,a}{31\,\text{P}_1} \ldots\ldots\ (g)$$

Let b = breadth of bar,

and d = depth of bar.

Assume that a cubic inch weighs $\frac{5}{18}$ lbs. (*i.e.* 480 lbs. per cubic foot), then

$$p\,a = \frac{5}{18}\,a\,b\,d = \frac{20}{3}\,b\,d, \text{ if } a = 24 \text{ inches.}$$

For the first bar, $p\,a = 3.755$ lbs., $b = 1.535$ inch, and $d = 0.367$ inch.

For the second bar, $p\,a = 2{,}024$ lbs., $b = 0{,}553$ inch, and $d = 549$ inch.

Find the value of the first number of (g), all the quantities in the second number being given.

$$\therefore \frac{\text{P}_2}{\text{P}_1} = \frac{49}{31} + \frac{24 \times 20\,b\,d}{31 \times 3 \times 82.84}.$$

For the first bar this $= 1.581 + 0.035 = 1.617$.

For the second bar this $= 1.581 + 0.019 = 1.6$.

In this experiment $\frac{52.}{82,84} = 1,593.$

This result may be considered to establish the essential correctness of the theory.

Next, a piece 3 feet $11\frac{1}{2}$ inches long was taken from each end of each bar and the central span was covered by the remaining piece from each bar (4 feet $4\frac{3}{4}$ inches long).

If the origin and axes remain as before, and the weight P be applied at D the equation of moments about any point in in D C is

$$E\,I\,\frac{d^2y}{dx^2} = \frac{p}{2}\left[2a-x\right]^2 - V_2\left[2a-x\right] \ldots (a)$$

Integrate (a) from $x = a$ to $x = x$

When $x = a$ then $\frac{dy}{dx} = 0$

$$\therefore E\,I\,\frac{dy}{dx} = \frac{p}{2}\left[4a^2x - 2ax^2 + \frac{x^3}{3} - \frac{7a^3}{3}\right] - V_2\left[2ax - \frac{x^2}{2} - \frac{3a^2}{2}\right] \ldots b)$$

Integrate (b) from $x=2a$ to $x=x$

When $x=2a$ then $y=0$

$$\therefore E\,I\,y = \frac{p}{2}\left[2\,a^2x^2 - \frac{2\,a\,x^3}{3} + \frac{x^4}{12} - \frac{7\,a^3x}{3} + \frac{2\,a^4}{3}\right] - V_2\left[a\,x^2 - \frac{x^3}{6} - \frac{3\,a^2x}{2} + \frac{a^3}{3}\right] \ldots\ldots (c).$$

Take (c) at D, then $x = a$ and $y = y_3$, say,

$$\therefore E\,I\,y_3 = -\frac{p\,a^4}{8} + V_1\frac{a^3}{3} \ldots\ldots\ldots (c)'$$

But from the principle of the lever

$$V_2 = \tfrac{1}{2}\,P + p\,a$$

$$\therefore E\,I\,y_3 = \frac{a^3}{6}\left[P + \frac{5}{4}\,pa\right] \ldots\ldots\ldots (c)''$$

To obtain $\frac{y_3}{y_2}$ eliminate V_1 or V_2 from $(c_2)'$, $(c_3)'$ or $(c_4)'$ by (h) and (k).

$$\therefore E\,I\,y_2 = \frac{a^3}{186}\left[13\,P_1 + \frac{59}{4}\,pa\right] \ldots\ldots (l)$$

then divide $(c)''$ by (l)

$$\therefore \frac{y_3}{y_2} = \frac{124\,P + 155\,p\,a}{52\,P_1 + 59\,p\,a} \ldots\ldots (m)$$

For the first bar if the weight $P = P_2$ (*i.e.*: 82,84 lbs.), from (m)

$$\frac{y_3}{y_2} = \frac{10272,16 + 582.12}{2704 + 221,68} = 3,71.$$

The value obtained from the experiment was $\frac{y_3}{y_2} = 3,77.$

For the second bar, if $P = P_2$, from (m)

$$\frac{y_3}{y_2} = \frac{10272,16 + 313.72}{2704 + 119,41} = 3,75.$$

The value obtained from the experiment was $\frac{y_3}{y_2} = 4,06$, but as we shall show, the bar was in this case loaded much beyond elastic limits, and the deflection was therefore greater than could be accounted for by elasticity alone, though not differing very widely from that within elastic limits.

For the first bar, if $P = P_1$ in (m),

$$\frac{y_3}{y_2} = \frac{6448 + 582.12}{2704 + 221,68} = 2,4$$

the result obtained from experiment was

$$\frac{y_3}{y_2} = \frac{1}{0,419} = 2,39.$$

For the second bar, if $P = P_1$ in (m),

$$\frac{y_3}{y_2} = \frac{6448 + 313.72}{2704 + 119,41} = 2,39$$

The value obtained from experiment was $\frac{y_3}{y_2} = \frac{1}{0,391} = 2,57$, but the bar was in this case also loaded somewhat beyond elastic limits, as indeed were both bars in these last four experiments. The first bar seems to have been of better material than the second.

To find the resistance which the bars oppose to rupture or to flexure, use the formula proved by Weisbach and other writers on the resistance of materials for a rectangular beam (of span $= 2a$), loaded with a weight P and with the uniform load $2\,p\,a$

$$\therefore P = \frac{b\,d^2}{3\,a}\,T - p\,a \ldots\ldots (n)$$

According to Weisbach when $T = 17000$ lbs., (n) gives the value of P which will strain a wrought iron beam to the limit of elasticity.

For the first bar, from (n), $P = 49.5 - 3.75 = 45.75$ lbs. which is the weight that placed at the centre of a four foot span will strain the bar to the limit of elasticity, but there are indications that this first bar was of unusual elasticity, which are derived from the observed valves of y_2 and y_3. So that it no doubt afforded a much greater resistance than the above before passing elastic limits. Similarly for the second bar, from (n) $P = 39.36 - 2.02 = 37.34$ lbs. There

are no indications in the observed deflections of the second bar that it was of extra quality, but the contrary.

It will then be perceived how truly it was overloaded by a weight of 82.84 lbs. at its centre, and that even 52 lbs. was sufficient to cause an observable deviation from elastic flexure, which entirely accounts for the discrepancies between the ratios derived from computation and experiment.

STUDIES RELATIVE TO THE IMPROVEMENTS WHEREOF THE CONSTRUCTION OF METAL-WAYS IS SUSCEPTIBLE.

By M. D. Soignie, Engineer, Brussels.

Journal of the "Iron and Steel Institute."

Among the causes which are opposed to the beneficial development of the construction of railways there are two, which are the principal that are indirectly connected with the great industry of the manufacture of iron and steel—that is to say, first, the considerable expense which the working of railways cause for maintenance; second, the too heavy cost of the first establishment of the permanent way properly so called.

These studies have for their object the discovery of a means of sensibly lessening these expenses in order to permit companies to work advantageously lines established in localities but little favored, and to thus rapidly increase the sum of the moral and physical well-being which these railways are destined to produce. Our attention has notably been drawn to the increase of the resisting quality of the iron rail; to the extension of the duration of its supports; and to the means of arriving at the passage of heavy gradients with locomotives of relatively light weight.

In order to attain these ends, we have imagined:—1st. A process of lamination calculated to improve the quality of the T rails. 2d. A new form of rails sensibly increasing their durability, other things being equal. 3d. A system of making rails with an entire super-raised face. 4th. A system of entire metallic way applicable to lines of large traffic, tramways, and lines in the interior of mines. 5th. A system of fastening with bolts with elastic pressure. 6th. A rail with an arched rolling crown increasing the adherence (bite) of the locomotive.

We will briefly describe these systems. Experience demonstrates that the resistance of iron rails is no longer sufficient to bear, during a lengthened period, the enormous traffic which is at present developed upon railways; that this deterioration has become so rapid, is ascribable, in our opinion, to two causes. To the decrease in the quality of the iron used in the manufacture of the rails, on the one hand; to the great weight per locomotive axle which their construction entails, on the other hand. The decrease in the quality of the iron of the rails arises from the use in the blast furnaces of an excessive proportion of silicious ores, of slags, which affords a ringing iron, but an iron breaking without tenacity; this decrease is again induced by the tendency of the manufacturers to finish their rails at too high a temperature. The impoverishment of the strong iron ores, the vignole shape given to the rails, compel the makers to act to a certain extent in this manner. Our system of lamination has for its object the avoidance, within the limits of possibility, of this state of things. In order to correct the deficiency of tenacity in the flanges of the rails, the dominant cause which augments their deterioration, we remedy thus:—1st. By a much more energetic compression of the iron forming the T rail. 2d. By a welding at a less temperature at the finishing rolls, without fearing the rending of the flange of the rail. In order to attain these results, the rail prepared by the ordinary method up to a certain point is completed in our special rolling mill, which is composed of three finishing rolls of a dimension of 0.70 m. at least, traveling at the rate of 1 m. per second, at the most, of which two are horizontal and the third vertical, cast in a mould intended to compress, temper, and polish highly the crown of the rail. As the finishing rolls are usually arranged, the swelling of the flange of the rail is obtained by the flattening or compressing of

the iron in the finishing grooves. This effect is evidently very prejudicial to the tenacity of the iron, inasmuch as instead of compressing the molecules, they are dilated exactly at the spot where the wheels most sensibly infringe on the rails.

By our arrangement, instead of dilating the iron, we strongly compress it, absolutely as would be done by the forge-hammer acting upon the crown of the rail, and with so much the greater efficacy, as the process of the welding is slow, and the diameter of the rolls large. On the other hand, it is well known that the more granulated iron is laminated at a low temperature the closer the pores become attached, which renders it more pliant and more hard. The contrary effect takes place when the same iron is finished hot, and that is what is effected with the mills of three rolls that are used in the present day. We avoid, moreover, this inconvenience without apparatus. The slow lamination, added to the continuous watering of the vertical compression cylinder, draws out the flange of the rail at a relatively low temperature, at the same time giving to it a sort of tempering which considerably augments the hardness and tenacity of the iron. This retardation in the definite lamination will not, moreover, produce rending in the flange of the rails; it is known that that never takes place in the last groove.

2d. Rail with crown super-raised.

Experience demonstrates that the deterioration of the T rail is so much the more prompt, the more decided the flattening of the head of the rail is in consequence of the wear and tear (friction). In fact, it must be so, inasmuch as the bearing of the tires of the wheels then act upon the edges, which are always the most feeble points of the rails; the tangential efforts of the wheels thus augmenting by the breadth of contact, this course of destruction becomes added to the former.

The action of the flange of the wheel tire upon the edges of the rails is also very detrimental, particularly at the curves, because the weight thus becomes localized upon a very small surface, where the iron offers the least guarantee of resistance. The form recommended, if given to the T rail, obviates entirely these inconveniences. The form under notice retains the breadth of the upper zone of the rail, whatever may be the wear and tear, within suitable limits, and the weight can no longer act upon the edges of the rails, but only towards the centre where they have a considerable resistance, and where the quality of the iron is always superior. It is known by mechanical action of cylinders that the iron is always less sound towards the salient points than towards the centre of a section.

Experiments, carried on for the last two and a-half years, corroborate completely our provisions. They prove by evidence that the duration of these rails is more than tripled; and even rails of the description laid down since the 30th of May, 1871, upon a gradient of twenty-five millimetres, where, according to an official report, the rails of the usual form did not last three months, are still in good condition, although very heavily used, that is to say, that up to the present time their duration is nine times greater than the rails of iron that were previously laid down upon the same place. These facts require no commentaries, and will make it comprehensible, we hope, that the interests of masters of Ironworks and Railway Companies is closely linked with the adoption of this practical form very suitable to bring up again the use of iron rails.

3d. Method of manufacturing the rail with a super-raised crown of steel.

The super-raised crown of rails of the form whereof we have just made mention, being of steel, it can be easily comprehended that the duration of such rails will bear comparison with those of the best rails made entirely of Bessemer steel. This form permitting moreover the trimming in the portion of steel in the interior of the mass, it will be much easier to weld this portion in iron and to be thus able to obtain mixed rails at a moderate figure, capable of resisting the most destructive traffic.

4th. System of line entirely metallic.

The substitution of iron for wood, as the support of the rails, interests as well ironmasters as the workers of railways. Our system, sanctioned by experiments that have been carried on for nearly three years, has this remarkable characteristic, that similar lines can be established in ordinary times at a less price for the first laying down thereof than the vignole line

upon wooden sleepers. Enormous savings in maintenance evidently emanate from this appliance.

This metallic line laid down, and permanent, is constructed of rail supports of iron; that is to say, vignole rails carrying invariably their supports, easily transported in that state, connected together by tie pieces. If a rail becomes defective it can be raised together with its supports, and is replaced by another rail and support. The support of the first rail can be used again. These rail supports of a new sort are upon a different principle to those upon which the English Barlow rails and the German Hartwich rails rest, without having the incoveniences of these latter. As the iron supports possess a duration almost indefinite, it is provable that after 36 years working, the kilometric saving realizable is more than 174,000f. The same system slightly modified applied for tramways afford savings even still more considerable. For the railways in the interior of mines it also offers great advantages, and our system of tie piece may there supersede the use of wooden sleepers. It is evident what fresh and important outlets the iron-works may find by the application of this means, the first expense no longer being an obstacle to the use of iron as the support of rails.

5th. System of splicing with bolts and elastic fastenings. The screws of the fish bolts, such as are used in the present day, under the influence of the tremulation caused by the passing of trains, soon become loosened, and consequently the splicing fails in its intent. It happens also that the violent shocks sustained by the nuts break the worms of the screws, and render the bolts unserviceable. The rusting of the threads of the screws is also a case of waste. Our system obviates these inconveniences by means of simple appendages to be placed below the flat of each screw. The appendages are composed of a washer of India-rubber encircled by a ring of iron upon which the flat rests after being fastened. By this means, as experience proves, the shocks are deadened, and the threads of the screws thoroughly preserved. The junction of the rails is, therefore, much more perfect, the roll of the carriages more gentle for travelers, and the preservation of the material stationary. The Belgian Government has resolved to apply this system of splicing, which does not cost more than about 60 cents per pair of splints. This system does not entail any alteration in the form of the bolts, nor in the splinting plates. It is consequently very easy for companies working lines to apply the same.

6th. Rails with crowns striated.

It is known that the adherence (bite) of the locomotives corresponds to a fraction of the total weight divided between the coupled wheels. It is proved also that this friction increases in an inverse ratio to the surfaces in contact with the wheels. It is this latter property that we utilize to prevent the sliding of the wheels upon heavy gradients, by supposing the useful adherent weight of the engine inferior to the corresponding power of the locomotive. For this purpose, we make upon the crown of the steel rail, grooves inclined 25 degs. upon the arch sufficiently close, in order that there be no solution of continuity in the rolling. It is perceptible that in this way the pressure of the tires per square centimetre is nearly doubled, and that the sliding of the wheels equally weighted ought to be effected with much greater difficulty. We have not, up to the present time, been able to determine this coefficient, having experimented upon lines striated perpendicularly to the axis, but it is certain that the bite is considerably increased. Although the sliding of the wheels upon these rails takes place less rapidly, we do not think that the resistance to the rolling will sensibly be increased, since the frictions of the sliding, or of rolling, are quite different. If the ulterior experiments are conclusive, these striated rails which would be laid down solely upon heavy gradients, would effect a complete transformation in the construction of the locomotives, and even in the railways, because the weight and axle might be reduced. The rails and the supports would consequently suffer much less. To ascend very great gradients upon a railway with stiff curves would no longer be a problem almost unsolvable. We draw the attention of engineers to this innovation.

Steel Rails on the Paris, Lyons and Mediterranean.—It appears that steel rails have now been laid down over 207½ miles of this system. Of the section thus steel-railed, 160 miles are comprised in the main line between Paris and Marseilles, in which, of course, the heaviest and most important traffic occurs.

ON PHOSPHORIC BRONZE AND ITS PRINCIPAL INDUSTRIAL USES.

By M. C. Montefiore Levi, Val Benoît, Liege.

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Although the subject of the present note might be considered as not strictly within the limits of the subjects to be submitted to the discussion of the Iron and Steel Institute, it nevertheless bears such an intimate relation to the methods of manufacture of iron and steel, that we do not hesitate to bring it under the attention of the Institute.

Our intention is not to establish any comparison between phosphoric bronze on the one hand, and iron and steel on the other, although such a comparison might present a certain interest, but if we take into consideration the importance of being able to produce by casting, that is to say, independently of any complication of shape, a metal possessing the qualities of hardness, absolute resistance, and elasticity in a higher degree than iron, and almost equal in certain cases to steel, together with the faculty of varying at will, and within very wide limits, any or all of these qualities; when, moreover, the metal may be considered as practically inoxidizable, when it shows but a slight friction against iron or steel, when it does not vary in structure by shocks or concussions, however often repeated, and preserves the entire intrinsic value of the metal when worn out or otherwise out of use, it will be admitted that the study of the qualities of such an alloy is of considerable interest to all who construct or use the numerous tools and powerful engines required for the production of iron in its many varieties.

The attention of the readers of English and foreign reviews and scientific journals has been on more than one occasion drawn to phosphoric bronze. We may specially mention the *Engineer* of the 8th July, 1870, and the 23d February, 1872, and *Engineering* of the 9th September, 1871, and the 4th October, 1872. These articles refer more particularly to the origin and to the first trials and industrial appliances of phosphoric bronze.

Prolonged experience in the manufacture has produced a more perfect knowledge of the properties and preparation of the alloy; it is thus that a far superior degree of resistance and of elasticity has been attained, while it has now become easy to give either of these qualities the desired predominance together with more or less hardness according to the special purpose to which the metal is to be applied.

The following table shows the result of five trials of tensile strength, made by Mr. Kirkaldy upon bars composed of one identical alloy, submitted to different processes of manufacture:—

Nos.	Ultimate Stress per Square In. Lbs.	Elastic Stress per Square In. Lbs	Ultimate Permanent Extension. Per Cent.
1.	74·966	55 800	2·55
2.	73·987	55 200	3·20
3.	63·653	40·500	9·40
4.	54·060	26.300	31·30
5.	50·120	21·700	39·10

The Ministry of Public Works for Germany, struck by the remarkable qualities of the alloy, ordered, as a work of public utility, a series of trials to be made at the expense of the Government. As these trials, similar in nature to those made constantly during the last eight years upon the iron and steel employed in the manufacture of rolling stock and railway plant, are of considerable importance, we will in a few words describe the means used and the end attained.

The trials at Berlin have proved the correctness of the hypothesis so often broached, that iron and steel, if submitted to continually repeated efforts of tension, torsion, or flexion, give way, probably in consequence of a molecular modification of structure under an effort often considerably below that of their absolute resistance under one single strain.

These trials were undertaken by the Prussian Government with the object of establishing as a fact, that the absolute resistance and elasticity of a metal being known, such metal can only with perfect security be submitted to a limited given number of strains of a given strength in all cases inferior to the limit of its absolute resistance. M. Reuleaux, Conseiller intime, and M. Spankenberg, engineer, are conducting these trials with phosphoric bronze. Highly interesting and elaborate details of the methods and apparatus employed by them may be found in the work of M. A. Wöhler, entitled

"Ueber die Festigkeitsversuche mit Eisen und Stahl. Berlin, 1870. Ernst ü Korn."

The first series of these experiments with phosphoric bronze as compared with ordinary bronze or gun-metal, were begun in April and ended towards the middle of May of the present year, with the following results:—A bar of phosphoric bronze was submitted successfully to 408,230 tractions, with an effort of 200 cwt. per square inch, while a first bar of ordinary bronze broke at an effort below 200 cwt. and a second bar resisted only 4,200 tractions. A second bar of phosphoric bronze has, at the present time, resisted 147,840 tractions with an effort of 250 cwt. per square inch, and this experiment is still in progress.

In a trial for flexion, with a maximum strain of 200 cwt. on the external fibres of the bar, these fibres alone were broken through after 862,980 flexions, while a similar bar of ordinary bronze, under the same strain, was broken completely through after 102,650 such flexions. A second bar of phosphoric bronze, under an effort of 180 cwt. per square inch, has, up to this date, borne 1,260,000 flexions without as yet showing any signs of deformation or of rupture.

We now come to a series of industrial appliances. A peculiar composition of phosphoric bronze, destined specially to resist friction, has been in use for several years on a large scale for bearings, particularly for rolling stock, and, among others, the Grand Central Railway Company, of Belgium, employed these bearings exclusively for all its cars and carriages. Many works, both in Belgium and Germany employ this alloy for engine and machinery bearings. The trials made have shown that the wear by friction is about five times less than that of ordinary bearing brasses, while the axles remain unaltered. Several ironworks, among which we may mention Messrs. Gillieaux and Co., at Charleroi Blondiaux and Co., at Thyle-Chateau, Thorneycroft, at Wolverhampton, and De Wendel and Co., at Hayange, make constant use of large toothed wheels, in phosphoric bronze, for the gearing of their rolling mills in all cases where the shocks are severe. Experience has shown that in no case has a tooth of such a wheel been broken, and that the wear is less than half that of ordinary bronze. (See, for further particulars concerning this special appliance, and also on the use of phosphoric bronze for transmission shafts for rolling mills, a note published in the "Bulletin du Museé, de l'Industrie of Belgium.")

In the February number of *Engineering*, for 1873, an article was published on the use of phosphoric bronze for tuyeres, showing that such tuyeres are much superior to those in ordinary bronze, and that after a year's service they show neither fissure nor incrustations of slag or cinder. These tuyeres, already largely used in Germany, are now being tried both in England and in France.

The great resistance of phosphoric bronze has led to its use for the manufacture of cylinders both for steam fire-engines and for hydraulic presses. Messrs. Merryweather have applied it to the first of these purposes, as may be seen in all the fire-engines sent by them to the Exhibition at Vienna. Messrs. McKean and Co. have also employed it in the construction of the apparatus they have made for the boring of the St. Gothard tunnel. The great elasticity of phosphoric bronze, and its easy friction on iron, have been very successfully taken advantage of in the construction of packing rings for steam pistons.

Phosphoric bronze may be drawn out into wire, and by this process it acquires a resistance at least equal to that of any other metal capable of being drawn into wire. The following table gives the results of trials made at Mr. Kirkaldy's of such wire:—

Metals.	Pulling Stress per sq. inch. As drawn lbs.	Pulling Stress per sq. inch. Ann'l'd. lbs.	No. of Twists in 5 inches of Wire. As drawn lbs.	No. of Twists in 5 inches of Wire. Ann'l'd. lbs.	Ultimate extension in per cent.
Phosphoric Bronze	102·750	49·351	6·7	87·0	37·5
Do.	120·957	47·787	22·3	52·0	34·1
Do.	120·950	53·381	13·0	124·0	42·4
Do.	139·141	54·153	17·3	53·0	44·9
Do.	159·915	58·853	13·3	66 0	46·6
Do.	151·119	64·569	15 8	60 0	42·8
Copper	63·122	37·002	86·7	96 0	34·1
Steel	120·976	74 637	22·4	79·0	10·9
Best Charcoal Iron	65·834	46.160	48 0	87·0	28 0

Besides its high absolute and elastic resistance, phosphoric bronze possesses in common with all alloys, where copper predominates, the advantage of not becoming crystalline, as is the case with steel and iron, under repeated concussions. It is, therefore, well adapted for the

manufacture of mining and other ropes. The prime cost is higher than the ordinary material, but it is probable that the cost in the long run will be less, as while resisting atmospheric and corrosive influences, it preserves, when worn out, its intrinsic value.

Phosphoric bronze of a suitable composition can be perfectly rolled and hammered. In Russia, several millions of cartridges have been made of this metal, and have been shown to bear firing as often as 120 times in succession, without being torn or otherwise injured.

As sheathing, it resists the action of sea water much better than copper. The following table gives the comparative result of six months action of sea water on rolled phosphoric bronze on the one hand and of yellow sheathing metal on the other, the surfaces acted upon being equal in size.

Metal.	Weight before Immersions.	Weight after Immersions.	Loss.	
	Kilogs.	Kilogs.	Kilogs.	Per cent.
Sheathing Metal	33·825	32·805	1·020	3·015
Do.	40·413	39 160	1·253	3·100
Phosphoric Bronze....	31·615	31·260	0·355	1·123
Do.	51·970	51 350	0·620	1·193

A similar trial, made for the purpose of ascertaining the difference of resistance to the action of an acid solution between rolled phosphoric bronze and copper, showed for three months action of sulphuric acid marking 10 degs. Baume, at the atmospheric temperature, a loss of 4.15 per cent. in the copper, and of only 2.3 per cent. in the phosphoric bronze.

Trials have been made by several Governments in regard to the use of phosphoric bronze for artillery purposes. In every one of these trials, the resistance (toughness) of the alloy has proved superior to that of ordinary gun metal, and it is only at this point of view, which alone interests its industrial appliances, that we refer to these trials in the present paper. In Belgium, at comparative trials made with bursting charges, the ordinary bronze gun burst explosively at the second round with 1,250 grms. of powder, and a projectile of 8,518 grms., while the phosphoric bronze gun resists this charge perfectly, the normal charge being 500 grms. of powder and a shot of 3,000 grms. In France, at the comparative trials with bursting charges, the ordinary bronze gun burst explosively at the second round with 1,500 grms. of powder, and a projectile of 16,000 grms., while the phosphoric bronze gun, after firing five rounds with a similar charge, burst only at the second round, with a charge of 1,750 grms. of powder and a projectile of 20,000 grms.: the cylinder had, however, got jammed into the gun. The normal charge was 550 grms. of powder and a shot of 4,000 grms. In Prussia, the comparative trials were made by firing constantly normal charges, and turning off a certain thickness of metal in the chamber after each fifty rounds. It was found that the dimensions of the phosphoric bronze guns were only altered by the firing, when the thickness of the metal had been brought down below that adopted for steel guns of the same calibre.

The Belgian Government has accepted the phosphoric bronze for the manufacture of the box of the Comblain Rifles, and for the harness buckles of the cavalry.

At the present time, besides the works at the Valbenoit, near Liége, three companies are in existence for the manufacture of phosphoric bronze, namely, Messrs. G. Höper and Co., at Iserlohn, in Germany; the phosphoric Bronze Company, at Pittsburg, in the United States; and the Phosphoric Bronze company, Limited, 110, Cannon Street, London, in England. The latter has exhibited several of the appliances of this metal at the Kensington Exhibition.

THE DELTA OF THE DANUBE.

By Sir Charles Augustus Hartley.

From Proceedings of the Institute of Civil Engineers.

The Danube, after a course of 1,700 miles, during which it receives more than four hundred tributaries, and drains upward of 300,000 square miles of country, passes the Bulgarian town of Isaktcha—the inland limit of the Commissioner's jurisdiction—in a single channel 1,700 feet in breadth and 50 feet in depth. Isaktcha is situated

on the right bank, at a distance of 40 English miles below the large corn-exporting port of Galatz. Isaktcha is 76 miles from the sea, following the course of the Kilia branch of the Danube; 78 miles by the Sulian branch; 90 miles by the St. George branch; and 58 miles from the sea in a straight line.

At 15 miles below Isaktcha the head of the delta is reached, at a spot called Ismaïl "chatal" or fork, and it is here that the fresh waters divide never again to reunite; as seventeen twenty-seventh of their volume pass onward in an easterly direction by the Kilia branch, and the remaining ten twenty-sevenths take a south-easterly direction by the Toulcha branch.

The Kilia maintains a wide and deep channel for 12 miles N. E. of the chatal to the town of Ismaïl, whence a communication by water exists with Lake Yalpuc, at the upper end of which is the frontier town of Bolgrad. Ismaïl occupies a fine situation on the left bank, but is of slight commercial importance. Its once famous fort was totally destroyed, soon after the conclusion of the Crimean war. From Ismaïl the Kilia trends, for about eight miles, in a S. E. direction, to a bend which directs the waters again to the N. E. Soon afterwards the river is divided into three branches, all of which maintain a navigable depth.

These meet together again at Staroi-Kilia, at about two miles below the town of Kilia, and 44 miles from the chatal. Down to this point the greater portion of the left bank of the Kilia forms the southern boundary of the great Russian Steppe, and is raised far above the level of inundation.

It is only here that it assumes the character of the opposite bank, which is liable to be flooded, throughout its entire length, during times of extraordinary high water. At 5 miles below Staroi-Kilia, the river again separates into three branches, which, after a course of 12 miles, once more unite and flow in a single channel, for four miles further, to the large basin of Vilkovi, situated at four miles from the N. E. angle of the delta.

Between this basin and the chatal, the course of the Kilia, although often separated by numerous islands, continues to pursue, in all its different channels, between well-fixed banks, a sufficient navigable depth for ships of the largest burden.

Below this point, however, these advantages are lost, for the Vilkovi basin is the root of a branch called the Stambul, which withdraws to the S. E., through swampy ground, half the volume of the Kilia; of the Ochakof, which bears to the N. E., one fourth its volume; and of three other branches, one to the left of the Ochakof and the other two to the right, which absorb the remainder.

These five branches, moreover, afterwards split into smaller channels, so that finally the waters of the Kilia are delivered to the sea by at least twelve distinct mouths, not one of which is navigable, except for fishing vessels.

At 11 miles below Ismaïl chatal, the Toulcha branch separates into two channels, the St. George and the Sulina. This point is called the St. George chatal.

The course of the St. George is generally in a S. E. direction; it bears with it four-fifths of the waters of the Toulcha branch, or eight twenty-sevenths of the volume of the main river at Isaktcha; its average width is 1,200 feet, and at seasons of extreme low water the depth of its navigable channel is nowhere less than 16 feet.

At two miles from its chatal, the St. George commences to skirt the foot of the Besh-Tepeh hills, with which it continues parallel for about 10 miles. It then quits its hitherto nearly straight course, and commences the first of a series of windings, for which its central and lower portions are remarkable. From the ample and uniform depth and width of the river, however, these windings are not such obstacles to the navigation as might be supposed. At 29 miles from the St. George chatal, a small stream called the Donavitza, branches off from the right bank, and, after a long and tortuous course, communicates with the vast shallows of the salt-water lake of Raselm. This lake is connected with the Black Sea, by a small channel called the Portiza, the mouth of which is barely navigable for small boats. Owing to this separate outlet to the sea, the Donavitza has been termed, by some writers, a branch of the Danube, but its insignificant section, of less than 50 square yards, by no means entitles it to such an appellation. At the small hamlet of Galinovak, 42 miles from the chatal, such a very sharp bend in the river is encountered that a cutting of only 1,700 feet in length, through the narrow neck of land separating its two parallel reaches, would shorten the course of the river full three miles.

Hence the river continues, with a broad and deep and less tortuous course, to the upper Olinka Island, where it separates into the branches of Kedrilles and Olinka, the former of which delivers almost immediately into the sea, in an E. direction, by a channel across the bar varying in depth from 5½ feet to 8½ feet, two-thirds of the volume of the St. George; while the Olinka channel carries off the remaining third, which is soon spread over the shallows that extend for some miles to the south of the Olinka Islands.

The general direction of the course of the Sulina is to the east. It abstracts one-fifth of the waters of the Toulcha branch, or two twenty-sevenths of the volume of the main river, and its navigable width is rarely more than 300 feet. Between the St. George chatal and the port of Sulina, there are nine shoals, the depth over which, during the seasons of low water, varies from 10 feet to 14 feet; although throughout the spring and early summer, when the waters are high, there is a depth of at least 16 feet over a width of 300 feet.

The entrance to the Sulina branch is of difficult navigation, owing to the acute angle which it makes with the Toulcha, and also by the sand-banks which are formed by the counteraction of the current, which, in entering the Sulina, is opposed in direction to the parent stream.

These obstacles, combined with the many intricate windings, and the numerous shallows which occur in the upper portion of this branch, render the navigation of the Sulina at all times hazardous and difficult. It is not until the extraordinary sinuosity known by the name of the letter M has been passed, and the last shoal, situated at 30 miles below the St. George chatal, has been avoided, that the anxious mariner feels secure for a safe course for the remainder of his downward voyage.

For the last 22 miles, the Sulina maintains a good, navigable passage to the sea, which is reached at 52 miles from the St. George chatal, or at 63 miles from the chatal of Ismaïl.

The Delta proper of the Danube may be briefly described as being bounded on the north by the Kilia branch, on the south by the Toulcha and the St. George branches, and on the east by the Black Sea. The enclosed space, which comprises an area of 1,000 sq. miles, is a triangular piece of land of which the Ismail chatal is the western apex, and the sea-coast extending from the mouths of the St. George to those of the Kilia, the base.

The Delta, with the exception of a few patches of cultivation on the borders of the St. George and Kilia branches, is entirely destitute of culture. Reeds of large growth cover the greater portion of its surface, and large swamps and fresh-water lakes are met with in every direction. On each of the islands of St. George and Leti, to the north and south of the Sulina, there is a large natural forest of oaks, many of which are three feet in diameter, and belts of willow trees clothe the convex shore of the St. George at every bend of its course.

The population of the Delta does not exceed 6,000 souls, and is chiefly composed of Greeks and Russians, although, since the Crimean war, all the islands below Isaktcha have been in the possession of Turkey.

The soil of these islands is composed of finely-comminuted alluvians, and is entirely free from stones, gravel, or even coarse grained sand. During extraordinary high floods, the Delta, being unprovided with artificial banks, to contain the swollen waters, is almost entirely submerged, while at seasons of drouth its banks are elevated from 10 to 12 feet above the level of the river, at the Ismaïl chatal, and from 8 to 10 feet at the chatal of St. George. In the lower reaches of each of the three branches, the level of the river is but little affected by the variations of the upland water.

Adjacent to its mouths, it never varies more than one foot, except when influenced by the wind.

During high floods, the inclination of the surface water of the Sulina branch is three inches per mile, but during extreme low water it does not exceed ¼ of an inch per mile. Along the seaboard, the shore is rarely more than two feet above the main sea level; near the St. George mouth, however there is a long stretch of sandhills from eight to ten feet in height, and adjoining the Stambul mouth of the Kilia are to be found dunes having an altitude of from 40 to 50 feet.

During ordinary high water, when the current has attained a velocity of from 2½ to three miles an hour, the Danube, before it divides at Ismail chatal, delivers a volume of water equal to 19½ millions of cubic feet

per minute, while during the dry season, when the current has been reduced to one mile an hour, the flow does not exceed 7½ millions cubic feet per minute. At times of extraordinary floods, such as occurred in March, 1861, the velocity is increased to five miles per hour, and the volume of water then delivered by the Danube to the sea was equal to 60 millions of cubic feet per minute, or eight times the quantity discharged at ordinary low water.

Great care has been taken to ascertain the comparative amount of deposit held in suspension during ordinary summer floods, and when the river has fallen to its lowest water level. These results will probably be published in detail hereafter. At present it is sufficient to state, that when the waters are most surcharged, they bear to the sea as much sedimentary as would be equivalent to a deposit of one inch to one cubic foot of water; and, that not more than one-fortieth part of this proportion is transported when the floods have subsided.

Thus, at the former period, upwards of 600,000 cubic yards of diluvial detritus pass into the sea, by the several mouths of the river, in twenty-four hours, and at the later period not more than 15,000 cubic yards.

The results of these investigations account, in a great degree, for the changes which take place, from to time, in the position and extent of the sand-banks forming the bars across the several mouths of the river. At times of high flood, these bars are further from the shore, their magnitude is increased, and the depths over them are diminished.

Thus the effect of a flood current, surcharged with earthy matter is, first of all by its quickened speed to deepen the channel over the bar. The displaced portion is pushed out into the shallows beyond, and there the river waters, checked by the nearly stationary waters of the sea, precipitate the heavier particles of the matter held in suspension to form a new bar; while the lighter particles are carried further, and widely distributed over the sea depths beyond.

The accuracy of this theory is further supported by the fact, which is well known to all the most experienced pilots on the river, that, during times of inundation from the upland waters, the bars are not only shallower, and further removed from the shore, but they are incrusted with hard sand which yields with the greatest difficulty to the plowing action of a vessel's keel.

This stratum of sand is undoubtedly of river origin, and evidently owes its freedom from impurity to the shifting and cleansing process exercised upon it by the waves during stormy weather.

The distance, and the height, at which the new bar is formed, are of course much influenced by the direction of the winds that happen to prevail at the time of the floods.

As soon as the floods subside the effect produced by the strong current ceases, the new formations are gradually pared down by the action of the ground waves; the alluvium of the river is precipitated nearer the shore, and the bars by degrees resume their old position with regard to the shore line; which they retain till the advent of another flood causes the same process to be repeated. The deposits which form the bars, although stretching across the mouths in every case, extend only a short distance to the north, but to a very considerable distance to the south.

This effect is produced by the combined influence of the northerly winds and of the littorol current, which latter, during these winds, and in calm weather, constantly flows towards the Bosphorus.

There are no tides in the Black Sea, and the level of the water along the coast of the delta is solely influenced by the opposing action of the land and sea winds.

Thus, when the westerly wind blows violently, the sea falls 18 inches below its mean level, and when strong easterly winds prevail, it rises 2 feet above the same point.

The northeast winds are the strongest, and blowing over comparatively shallow water, produce the most dangerous seas. The largest waves are, however, those produced by the southeast gales, which cross a reach of 500 miles.

The sea depths, opposite the delta, decrease to the north; thus opposite the St. George mouth, at 3 miles from the land, the sounding line gives 16 fathoms, whereas, at the same distance from the Sulina and Kilia mouths it gives but 10 fathoms. The sea slope, immediately in front of the Kilia delta coast line, is still more gradual, although, from the actual base of the Kilia, the bottom rapidly shelves off into deep water.

The distance, however, of the bars from

the shore, the rapid advance of the shelf seawards, and the large volume of water delivered to the sea, all tend to place the mouths of the Kilia in the worst possible condition for successful treatment.

The author instituted a careful comparison of the two accurate surveys, one by the Russian Government in 1830, and the other by the English Government in 1856, from which, it appeared, that during the interval, the shallows at its entrance, advanced fully one mile in, in the direction of the Sulina mouth. This startling extension, in so short a period, the uncertain and changeable nature of the many branches issuing from the Vilkovi, and the distance of the bars from the shore, were the chief considerations which caused the author to form an unfavorable opinion of the Kilia, in spite of its possessing the best river channel. He therefore recommended, in preference, the improvement either of the St. George, or of the Sulina, when the sea depths are greater, and the advance of the sand banks much less remarkable.

In comparing the merits of the latter branches, the author arrived at the conclusion, that, nearly in every respect, the St. George offered decided advantage over the Sulina. After the short description which has been given of these respective channels, it need not be said that the river portions offer no real obstacles, while at every turn of the upper reaches of the Sulina, disaster of every kind is imminent.

It is true that to reach the Kedrilles bar of the St. George, double the length of works would be necessary, and that, consequently the additional expense would be in the same proportion; but it is no less true, that if the sand banks were once passed by such works, the greater sea-depths opposite the St. George would insure, for a much longer period, a constant navigable depth at the sea entrance.

The St. George is not only situated at the salient angle of the Delta, but it is the easiest to reach, and is nearer by 18 miles to the Bosphorus than the Sulina.

It is also most favorably situated with regard to the safe manœuvering of vessels, during N. N. E. winds; as the tread of the coast toward the Portiza mouth gives more sea-room, and enables vessels, if caught in a northerly gale outside, to run for shelter under the lee of the S. W. shore of the Delta.

When the author presented his first projects, the commission had before it three other designs, by three eminent technical authorities who had visited the ground, each of whom advocated the adoption of a different branch.

The authors of these several reports differed widely in their estimates of the merits of the three principal branches, and of the difficulties to be overcome, in rendering them navigable for larger vessels.

In one respect alone all were agreed, and that was, in recommending that, in whichever mouth were chosen, the system of improvement should be that of guiding the river waters across the bar, by means of piers projected from the most advanced dry angles of the river's mouth; or, in other words, that of concentrating the strength of the river current by an artificial prolongation of the river banks into deep water.

In the midst of so many conflicting arguments, the English, French, Prussian, and Sardinian Governments referred the whole question to the decision of two military and two civil engineers, the former delegated by England and Sardinia, and the latter by France and Prussia. But this measure, instead of leading to a satisfactory solution, only complicated matters still more; for these gentlemen prepared a very able and elaborate report, in which they recommended the choice of the St. George branch with a sea entry and gates independent of the mouth; a project diametrically opposed in principle to the system of improvement, previously proposed by all the naval and engineering authorities who had visited the several mouths of the Delta and had studied their peculiarities on the spot.

In the mean time, the merchants of Galatz and Ibraila called loudly for some immediate improvement of the Sulina, and urged that the heavy iron rake which, it was alleged, had formerly been so usefully employed by the Turks in deepening the Sulina Bar, should be again applied for the same purpose.

In order to satisfy these demands, and ascertain the value of a means so simple, and so comparatively inexpensive, the commission not only caused the old Turkish rake to be dragged across the bar fifty times a day by a steamer, during three of the finest months of the year, but they also employed during the same time, a steam dredger, capable of lifting 1,000 tons per day, to turn over the bottom of the bar, with a view to enable the river current to

transport the disturbed material into deep water. Now precisely because this current was too feeble, and did not possess the transporting force required, these measures failed to produce any appreciable beneficial effect; and the commission, therefore, after having given the system a fair trial, abandoned it entirely.

The author considering, that, from motives of expediency, it might be deemed desirable to select the Sulina branch definitively, in preference to the St. George branch, had previously prepared an alternative design for permanent works at the mouth of the Sulina; and the Commission, on relinquishing the operations above described, resolved to improve the channel across the bar of that branch by means of guiding piers of a temporary character, but carried out on the lines which the author had designed for the permanent works. The commission arrived at this decision with the view of giving the speediest relief in the cheapest manner. But it was guaranteed that this provisional expedient should not prejudice the choice of the mouth, to be eventually selected for the permanent treatment.

The original design for the permanent works may be thus briefly described. The piers were projected to cross the bar, and terminate in a depth of 18 feet, in order that the proposed channel might be deepened by the concentrated action of the river current and that a good navigable channel should be maintained beyond the piers; it being assumed, that when the troubled waters of the river were brought into immediate contact with the littoral current crossing the pier heads, the fluvial matter would remain suspended until it was far removed from the entrance. With this object in view, the north pier was designed to be 5,850 feet in length, and the south pier 4,310 feet; their general directions to be E. by N., so as to shelter the port, and to allow vessels to enter during every onshore wind. They were to be constructed of "pierre perdue," surrounded by solid masonry and ashlar work, carried to the height of six feet above the water line; and their cost was estimated at £300,000 or £30 per lineal foot. The south pier was designated to be considerably shorter than the north pier, for two reasons; first it was considered unnecessary, and indeed undesirable that the piers should run parallel to each other until the bar was reached; and advantage was therefore taken of the south lip, beyond the opposite shore, to commence the south pier nearly 1,000 feet seaward of the commencemement of the north pier; secondly in order to shelter vessels entering and leaving harbor during the prevailing N. and N. E. winds, the north pier was designed to overlap the south by 600 feet, a length equal to the normal width of the river. Such was the first design, and, as the second only differed from it in the length of the piers, and in their comparative provisional character, reference need now only be made to these differences, without further allusion to the actual trace of the works, which was identical in both cases.

The author, having received the instructions of the Commission, proceeded to design works of a minimum section with regard to strength, in order to prolong the piers as far seaward as possible, for the smallest sum, and with the greatest speed. The problem submitted to him was to provide guiding works, which, for a sum limited to £80,000, should be carried out so far as to give an increased depth of at least two feet, and should have solidity sufficient to resist uninjured the attacks of a notoriously tempestuous sea, for a period of six or eight years. This duration of time was based on the assumption, that during such an interval, either the St. George would be opened or it might be considered expedient to limit the improvement of the Danube, to rendering permanent the provisional works at the Sulina.

The first idea which naturally presents itself to the mind, in designing such moles, in a country where stone is obtainable, and where skilled labor is only to be had at great cost, is the simple expedient of throwing down stones at random, along the line of the projected works. On consideration, the following objections to this plan caused the author to reject it. First, if carried to the surface of the water, the upper stones would be liable to displacement during gales, and the cost of such a mass of material would greatly exceed the limits of the proposed expenditure.

Secondly, supposing the stones to be only carried up within three or four feet of the surface of the water—a plan actually proposed to the commission by one of its technical advisers—the pier would form dangerous reefs, on each side of the entrance, and the escape of the water issuing from

the river over these reefs would greatly diminish the good effect sought.

It thus appearing that the employment of stone by itself, would not answer the purpose, the author turned his attention to the employment of fir timber, which can be purchased in any quantity, and of any size, at from 3d. to 4d. per cubic foot.

He then found that by combining third-class rubble with timber, he could construct the required length of pieces for a sum not exceeding the prescribed limits.

The first plan was to construct cribs from 30 to 60 feet long, of timber 12 inches square, firmly fastened together; to load them with stones and to sink them at intervals of 20 feet along the line of works, the whole being protected at the foot by rubble-stones. This plan, however, was not adopted, as the cost of the cribs, owing to the difficulty of fixing them, and their settlement in the sand, would have exceeded the original estimate. Choice was finally made of a structure composed of piling and "pierre perdue" surmounted by a timber platform 14 feet wide, strengthened by solidly-constructed cribs of the same width.

The works were commenced, April 21st, 1858. A temporary staging fixed on piles, driven by ringing engines, worked from barges, was run out from 200 to 300 feet in advance of the permanent piling; and although, during violent gales it was partially destroyed, the repairs were rapidly effected during fine weather.

The staging supported nine crab engines, each working a monkey, each weighing 15 cwts., and driving down daily, on an average, a pile 13 inches square, 16 feet into the hard fine sand of which the bottom is composed. By these means three rows of three piles each, at square distances apart of seven feet, were frequently driven in one day. They were then immediately secured by double longitudinal walings 12 inches by six inches, and double cross ties 12 inches by four inches, and 15 feet long, the whole being surmounted by two tram-pieces six inches thick, and planking three inches in thickness, at four feet above the level of the sea. From this permanent platform, the close piling on the side next the sea was driven, by six similar crab engines, following closely on the open seven feet bays in advance. The daily rate of progress during fine weather was 20 feet; and no sooner had this length of sheet piles been placed, than stones were thrown down to protect its footing in the sand, which without such protection, was liable to be washed away to such an extent by the beat of the sea, as to endanger the stability of the exposed close piling although driven 14 feet into the ground; and so serious did this scouring action become, when the skirt of the bar was reached, along the line of open piling immediately beyond the sheeting, that although confined to that locality, it threatened at one time to demand double the quantity of stone originally estimated.

As an instance of the power of this action—the result of attacks solely from the sea, unassisted by the river current—it may be mentioned, that a crib, 30 feet by 15, sunk in a position in nine feet of water, loaded with 130 tons of stone remained for nearly one week without settling $\frac{1}{100}$ of an inch. No sooner, however, was the foundation attacked by a heavy sea than the crib sank bodily four feet deep, in three days, and then only came to a bearing owing to the stonework, which in the mean time had been deposited around it almost to the level of the water, having arrested the scour. In the first instance bags of sand were made use of, to fix the bottom and to fill the holes which had been scoured out between the open piling. This expedient was economical, as long as old sacks were supplied at a merely nominal price; but when the supply failed and the cheapest kind of new canvas sewn into sacks was substituted, it was found, that bulk for bulk, the sand-bags cost as much as the stone without answering the purpose as well, thereupon the following plan was adopted, for 400 feet. Long rafts of unsquared timber, laden with fascines and stones, were sunk between the exterior open piles, as well on the river as on the sea-side, so as to cover the base of the embankment with a layer of four feet in thickness.

This arrangement was economical, and would have succeeded perfectly, had time been no object; but as the sinking of the fascines could only be accomplished during perfectly calm weather, the progress of the work became so slow as to necessitate the employment of some other system, which would insure greater rapidity of execution. Recourse was then had to a plan which answered as well in every respect, and by means of which the author has been able to complete the works within the original estimate, and in less time than at first specified.

The open pile-work was advanced with all possible expedition, and the proposed seat of the advancing pier was paved with stones delivered from barges.

This pavement withstood the attacks of the sea, and offered no great obstruction to the penetration of the street piles, which, without being shod were frequently driven 10 feet into the ground, after having been driven through eight feet of rubble-stones.

In throwing down the stones from the barges, care was taken to pitch them close to, and equally on each side of the sheet piling, until the stone-work showed itself above the water line; and then, after the wedge-shaped upper portion had been distributed over a wider base, by the action of the waves, to repeat the same process, until the slopes found their angle of repose.

In this way no more stone was employed than was absolutely necessary for the stability of the work, which, when completed, might be described as a mass of closely-packed third-class rubble, resting on a broad base, and narrowing upwards to a level slightly below the surface of the water, at which point it became a mere ridge resting against the close piling; the side slopes of its section varying from two to one near the pier heads, from one to one, and $1\frac{1}{2}$ to one, near the shore. The piers were completed on the 31st July, 1861, and the time employed in their construction was thirty-one months, exclusive of three winter months in each year, but inclusive of two hundred and seven days, during which it was impossible to work on account of stormy weather. The length of the north pier is 4,631 feet, and that of the south pier is 3,000 feet, and the depth of water in which they are built, varies from six to 20 feet.

In this construction 200,000 tons of stone, and 12,500 piles have been employed, and the cost per lineal foot has not exceeded ten guineas.

The stone which was used is a hard blue limestone, and was transported 58 miles by water, after having been, for the most part, carted two miles to the river bank at Toulcha. None of the stones were heavier than two men could lift, or less in size than a common brick, and their highest price delivered at the piers, including all charges, was 5s. per ton, and the lowest price was 4s. per ton. All the transverse and longitudinal timber, as well as the planking and fender piles, were oak, and their cost at the rate of 2s. 3d. per cubic foot. While the fir piles were delivered ready for driving for four pence per cubic foot.

The workmen, of whom there were generally 300, were composed of men belonging to upwards of ten different nations. Laborers were paid 2s. 6d. per day and carpenters 4s. 6d. per day. The foreman of the works, Mr. William Simpson, displayed an energy and ability in the execution of his duties which were creditable to him.

The earliest authentic document extant which shows the state of the Sulina mouth is the Russian Government survey of 1829.

The depth on the bar since the year 1829 has varied between the depths of seven feet and twelve feet; the least depth being found during the subsidence of high-water floods, and the greatest when the deposits lodged by these floods had been dispersed by the autumnal and winter gales. In July, 1857, when the works were commenced, the river margin of that portion of the Sulina bar which gave soundings of less than 15 feet, was 2,000 feet distant from the north promontory of the mouth, and 4,000 feet from its sea-margin. Near the centre of this long shoal the navigable channel was only nine feet deep. In November 1859, when the works had been brought to a close for the winter, the north pier had advanced 3,000 feet and the south pier 500 feet. The depth on the bar was then 10 feet.

From this period till the following April, although the works remained s ationary, the depth of the channel increased to 14 feet.

As this could only be attributed to the north piers, hopes were entertained that its action would be sufficient to maintain the improvement, which unaided, it had effected. These expectations, however were soon disappointed, for during the spring and summer months, the unusually high river floods caused such a deposit at the mouth, that in August when the north pier had reached the length of 4,600 feet, or to within 30 feet of its present extremity, the depth of the bar had diminished to $9\frac{1}{4}$ feet. The inadequacy, therefore, of a single pier to maintain an improved depth was fully demonstrated.

Every exertion was then made to bring the south pier into play.

Accordingly during the next three months it was pushed out 1,500 feet further, and as it was then brought to within a dis-

tance of 600 feet of the north pier, the good effect of concentrating the whole force of the river current directly on the bar became at once apparent. Thus on the 30th of November, there was a good navigable channel of twelve feet; on the 31st of December of 13 feet; and on the 28th of February, 1861, of 14 feet.

Then came the breaking up of the ice on the river, and the furious descent of the extraordinary high floods, which caused so much damage at Galatz, and submerged the whole Delta; but this time, the swollen waters being confined between the two piers, and being directed in a proper line, instead of causing a diminution of the depth, fairly swept away the remainder of the bar on to the south bank and into deep water. From that time to the present, the depth has never been less than 16½ feet, and frequently more than 17½ feet, over a navigable width of 500 feet. This result has been accomplished by works the cost of which has not exceeded the sum which was paid in one year only for lightening vessels over the bar, when its depth did not exceed 10 feet.

Nor is this the only subject for congratulation. The great gain to the shipping interest, in other and still more important respects, is incalculable. For some years an average of 2,000 vessels, of an aggregate capacity of 400,000 tons, visited the Danube, and of this number more than three-fourths loaded either the whole or part of their cargoes from lighters in the Sulina roadstead, where, lying off a lee shore, they were constantly exposed to the greatest danger. Shipwrecks were of common occurrence, and occasionally the number of disasters was appalling.

As an instance, on one dark winter night in December, 1855, during a terrific gale, twenty-four sailing ships, and sixty lighters, went ashore off the mouth and upwards of three hundred persons perished. At present no disaster is possible. Vessels may enter at any time with any wind.

Sulina, in fact, is now one of the best harbors of refuge in the Black Sea.

The summary of facts leads to the hypothesis, that if the good effects that have already been produced should now be as suddenly lost, the expenditure on the whole just described, would not have been unprofitably applied.

Fortunately, no such catastrophe is immediately impending; for the comparison of the plans of the mouth which were made by Mr. Hansford, the skillful surveyor of the Commissioners before the commencement and after the termination of the works, show that while deposits of a small extent have taken place in the interval to the south of the improved channel there have been no deposits whatever to the north.

This evidence is encouraging for the future, and sustains the position which has been so much insisted upon by the Commission, that the system of parallel piers, as applied at the mouth of the Sulina branch is the best that under the circumstances, could have been devised for an improved sea-entrance to the Danube, even with the certainty attached to it which is not denied—that to maintain the improvement, and to keep pace with the formation of new sand banks, or the growth of old ones, the guiding works must eventually be prolonged.

CIVIL ENGINEERING.

SUSPENSION BRIDGES.*

From the "Building News."

Until the completion of Hammersmith Bridge in 1824, there existed no example of this method of construction in the vicinity of London. Their history is, however, of very ancient origin, and they are adopted chiefly for spans too great to be crossed by girders or arches at a reasonable cost, or where a foot-bridge only of small span is desired. Humboldt informs us that numerous early examples exist in South America made from ropes 3in. or 4in. in diameter, formed from the fibrous portions of the roots of the American aloe. Such structures are asserted to have existed in America prior to the arrival of Europeans. Bridges composed of more durable materials also are found to have existed in these remote districts.

*Abstract of paper read before the Civil and Mechanical Engineers' Society.

An iron suspension bridge of fabulous origin is known to have existed in China. Numerous bridges on this principle are spoken of by various travellers in China, which are said to vibrate to and fro so much that persons crossing them are affected with sensations of fear lest they should come to grief while passing over. We have no record of the adoption of such structures to cross a river or valley by the Greeks, the Romans, or the Egyptians. The engineer, it is reasonable to suppose, has therefore obtained his first ideas for the construction of suspension bridges from the barbarians of America. Scamozzi mentions the existence of suspension bridges in Europe at the beginning of the seventeenth century, but as the mathematical knowledge requisite to determine their properties was not arrived at till the middle of the following century, it is doubtful whether such were constructed upon true principles. They were probably of short duration, as other writers are totally silent on the subject. The oldest suspension bridge in the United States was erected at the close of the eighteenth century. The old Winch chain-bridge, over the Tees, between Durham and York, chiefly for the use of miners, is said to be the oldest example in England. Wire suspension bridges were also made, though to no considerable extent, in Scotland at the commencement of the present century. Experiments were made by Telford when the bridge of Runcorn was under consideration, accounts of which are to be met with in various works, and their results applied to the consideration of suspended girders. Telford designed the magnificent bridge over the Menai Straits, separating the Isle of Anglesey from Carnarvonshire, and employed four sets of main chains, each consisting of four, making sixteen chains altogether, the tension in each of which was similar and uniform. Each chain was formed of five links 10ft. long, 3¼ in. wide, and 1in. in thickness, with chain plates to connect them at each end 1in. thick. Vertical rods supporting the framework for the platform are suspended from these chains at equal distances of 5ft. apart. In Mr. Drewry's excellent treatise on suspension bridges we are informed that the plan of operation in putting up the chainwork of this bridge was as follows:—"The chains were first put together in the tunnels, working up from the fastenings to the mouths of the tunnels by bringing down one link of each chain at a time, and bolting it to the one brought down before. Next, the chains were put together from the mouths of the tunnels up to the main piers, upon a scaffolding erected on the masonry between the pier and the shore, with the proper inclination for the backstays. The chains were then continued over the Carnarvon pier, hanging down loose nearly to the level of high water. This was done by suspending a cradle large enough for two men to sit in, from a crane arm set up on the top of the pyramid. The cradle was suspended by tackle, so that the men could slack it down or haul it up, to raise or lower themselves at pleasure. The links of the chain that were to be joined on to the ends of the chain hanging over the top of the pier were brought successively along the road to the front, or sea-face of the pyramid, through the arched roadway opening. Thence the link was taken up by a tackle from a pair of shears placed on the top of the pyramid, and lifted up to the height of the link it was to be fixed to, where the men in the cradle got hold of it and brought the two links together, and put the coupling bolt through them. On the Anglesey side of the Strait the chains were carried just over their saddles on the top of the pier, and their ends were retained by tackle made fast to them, and descending thence to capstans on the shore. The remaining piece or length of chain, which was to unite the two ends of the chains brought up from each shore, was laid on a raft 400ft. long and 6ft. wide, made of whole deal balks bolted together. One end of the piece of chain was first fastened to the end that hung over down to the water from the Carnarvon pier, and then the raft was floated across to the Anglesey pier, and the loose end of the chain upon it was fastened to the tackle that hung down from the pier. The tackle was then hauled up by the capstans fixed on the shore, and the chain raised gradually off the raft until the end of it was brought in contact with the end of the chain that hung over the top of the pier. The two loose ends were then bolted together, and the operation completed." The Conway Bridge is built on the same principle as that over the Menai Straits.

It is 327ft. in span, with a versed sine of curvature of main chains=22ft. 6in. There are eight chains, which were erected by means of strong rope cables reaching from top to top of towers, suporting a temporary platform. On this the chains were carried and fixed in position ; afterwards the platforms of wood were taken away, the rope cables slackened, and the chain lowered to its proper curvature. The Union Bridge, across the Tweed, was the first bar-chain bridge of considerable size erected in this country. It was designed and executed by Captain Brown. Distance between points of suspension, 449ft.; deflection, 30ft. The roadway, 18ft. wide, is supported by vertical 1in. rods, 5ft. apart, suspended from twelve main chains, arranged in couples, and forming three sets on each side of the bridge, one underneath the other. The Newhaven Suspension Pier, Brighton Chain Pier, Montrose Suspension Bridge, and other structures, were also executed by the same engineer. The Newhaven suspension pier, 700ft long and 4ft. wide, is divided into three spans, each supported by longitudinal girders, held up by vertical rods suspended from two main chains, passing over cast-iron saddles. The old Brighton pier consists of four main chains on each side, from which the platform is suspended by vertical rods, 1in. in diameter, 5ft. apart. In 1838 it suffered much damage during the storm, the roadway being carried partly away, and the suspension-rods broken. In the Montrose suspension bridge, scarcely second in point of construction to the Menai, the roadway is 412ft. long, and 12ft. wide and was suspended by 1¼in. vertical rods, without joints, 5ft. apart, from two main chains, each composed of bars 10ft. by 5in. by 1in., the versed sine of the catenary being 42ft. About ten years after its completion, about one-third of the platform gave way, in consequence of the failure of one of the suspension-rods, when rods of $1\frac{5}{8}$ in. diameter, with flexible joints at the level of the platform (to avoid any twisting that the undulatory motion might cause) were substituted for the old rods. A system of vertical diagonal trussing, 10 ft. deep, placed half above and half below the platform, was also adopted, to prevent undulation, as well as consequent oscillation arising from one side being raised by the wind at one end, while the lower side at the other end was depresssed. In the following year (1839), the bridge over the Menai Straits was severely injured by a storm, the carriage-ways being rendered impassable, and a portion of the suspension-rods torn away. The motion was stated to have been greatest about midway between the points of suspension and the centre of the bridge. The Hammersmith suspension bridge was executed by Mr. Tierney Clark. The large span is 422ft. 3in., the versed sine of the catenarian chain being about 29ft. The platform is divided into a carriage-way 20ft. wide, with footpaths on either side 5ft. wide. Two of the eight main chains on each side of the carriage-way have links consisting of six wrought iron bars 8ft. 10in. long from centre of the eyes, 5in. wide, and 1in. thick. The other chains on the outside of each footpath have only three lines of bars of the same dimensions in each link. The total length of the bridge from abutment to abutment is 822ft. 8in. The links are fastened to holding-down plates embedded in brickwork in abutments, pasing through tunnels 3ft. wide for the large chain and 2ft. wide for the small side chains, which pass down at the same angle as the chains of the central opening. In February, 1869, questions were asked in Parliament as to the stability of Hammersmith Bridge under the extraordinary strain brought to bear upon it on occasions such as the University boat-races, when not only is every available standing-room occupied, but hanging on the chains and climbing the suspension-rods are indulged in, regardless of the certainty which Tierney Clark never foresaw, namely, the uncommon and unusual load brought to bear upon his bridge.

To test the condition of the bridge, then, Captain Tyler on the part of the Government, with Mr. R. M. Ordish on the part of the Hammersmith Bridge Company, were respectively appointed to investigate in a thorough and practical manner its actual efficiency. This was done by removing at random some of the suspension-rods, as also taking a spare cross-girder which (cast at the same time—probably 1820—as the others) had been lying as a superfluous one in the dampness of alluvial soil ever since. The quality of the iron was carefully tested by Mr Kirkaldy, and the results were satisfactory. The suspension-rods, 1in. square,

withstood a strain up to 18 tons. The cross girders are of substantial 1¼ inches metal in the web, 3ft. 6in. between outside suspension points, 17 inches deep at centre, tapering outwardly to 8½ inches at those supports. The inside suspension-rods are keyed five feet nearer centre of girder, where the girder is 12 inches deep. These measurements were accurately taken. Owing to the misfortune which happened to the spare girder while being conveyed, owing to the carelessness of the carter, the girder being laid on its side, the jolting and jerking caused it to break of its own weight; hence only the quality of the metal was ascertained, upon which deductions and calculations were based, and a knowledge of its strength arrived at satisfactorily. In regard to the saddles and rollers of the chains, it might be asked if rollers are of any practical service whatever? Would not the friction of the rollers be so great as to require the tower itself to ease before the rollers revolved? It is noticeable that the Hammersmith Bridge rollers appeared rusted into their saddles or bearings, there being, notwithstanding, evidence of the chains having rubbed their under surface upon the rollers. A bridge of similar construction by the same engineer, consisting of four main chains composed of flat bars, was erected at Marlow some years ago. The total length is 426ft., and the deflection of the chains 18ft. 6in. In the Norfolk Bridge, of 284ft. span, there are three lines of chain each side, the deflection being 20ft. 2in. Here the backstays are not placed in the same angle as chains in the centre span. In the Broughton Suspension Bridge, near Manchester, of 145ft. 6in. span, with a deflection of 12ft. 6in., the platform is held up by two chains on both sides of the structure, resting on cast-iron suspension frames, in which due allowance is made for expansion and construction.* The Tiverton Suspension Bridge, over the Avon, near Bath, is supported by suspending bars averaging 2in. by 1in. placed 2ft. 6in. apart, and keyed into a cast-iron plate fastened to the towers. The bridge of Micklewood has its platform supported not suspended ; its span is 103ft. The cross girders are secured together by cross bracing, and rest upon iron frames, which are supported by chains on each side. The widest suspension bridge ever attempted in England is at Clifton. It is 702ft. 3in. in span., and 31 ft. wide. The versed side of the curved chain is 70ft. There are three chains supporting wrought-iron main girders, with cross girders of open work. The chains were carried upon the piers by saddles of wrought iron resting on cast-iron bed-plates fixed on cast-steel rollers. A girder bridge for the Charing Cross Railway being decided to be erected in place of the old Hungerford Suspension Bridge, the chains were purchased for a moderate amount, and adapted for use at Clifton. Mr. Barlow, in his account of the Clifton Bridge says, " The links were arranged in the old Hungerford Bridge so that the joints of the links in the upper chain were opposite to the middle of the links of the under chains, and the suspension-rods were carried by a jointed link in such manner that half the weight was borne at the point of the one chain, and the other half by the middle of the links and the other chain. In this mode of hanging the suspension-rods a transverse strain of considerable amount was brought upon the middle of the links of the chains. In the Clifton Bridge this was avoided. The suspension rods transmit their strain to the chain only at the joints. The result is that the links of the chain have no other strain upon them than that of the direct tensile strain in the direction of their length. The duty of maintaining an equal action upon all three chains in supporting the roadway is performed by the strength and stiffness of the longitudinal girders. The suspension-rods are attached to the longitudinal girders, each rod being furnished with a double adjusting screw at the lower extremity." The links were tested both in the Hungerford and Clifton bridges to a strain of 10 tons per square inch. The temporary staying necessary for their erection consisted of eight ropes of iron wire, each rope calculated to sustain 35 tons. Six of these supported a platform staging upon which the links were supported by packing pieces until the connection in the centre of the chain was made, when it was allowed to take its own bearing. The remaining two ropes were placed above the links to serve as a handrail on either side and were attached to the platform below by strong hoop-iron.

* In 1831 this bridge sustained severe injury by the vibration produced by a company of sixty soldiers marching over it.

Another rope was also fixed to carry a travelling framework supported on wheels, by means of which the links, tools, &c., could be conveyed from any one part of the work to any other part. The weight of the chain between piers was 550 tons. The Chelsea Suspension Bridge 704 ft. long, is divided into a central span of 333 ft. and two side spans of 166ft. 6in. Its width is 47ft. The chains are four in number two on each side, consisting of links 8in. wide, in lengths of about 16ft. from center to centre of pinhole. The deflection of the central portion is 29ft. The chains are carried over saddles resting on fixed massive cast-iron cradles, supported on cast-iron columns cased with ornamental cast-iron work, and weigh altogether 340 tons. At the abutments the chains are diverted to their moorings through tunnels placed at angle of 155 deg. with a horizontal line. Four temporary chains of 2in. wrought-iron rods, placed on each side of the permanent chain, were thrown across for their erection, by means of which the bridge-links were hoisted and fixed. In addition, four similar chains placed below these were thrown over to support a timber platform for the workmen. The suspension-rods are each divided into two at the chains by means of a crosshead or short bar fixed to the centre of the suspension-rod, and at the ends to two short rods, one of which is connected with the upper chain, and the other with the lower. By this means each chain is made to take an equal strain, since the leverage is the same on either side. We see, then, that in most suspension bridges the platform is suspended by vertical rods hanging from chains stretching across from tower to tower, by means of which the whole weight of the roadway and the moving load, generally estimated at from 70lb. to 90lb. per square foot, is transmitted through the chains to the piers. Mr. Dredge, of Bath, some years ago invented the taper-chain suspension bridge, with the object of rendering the roadway free from the effects of undulation and vibration. The invention consisted in supporting a great portion of the roadway directly from the standards on each side, thus leaving a diminished tension due to the chain, and in having the chains of such strength and size at the points of suspension as would suffice to support the maximum fixed or moving load to which they are at any time likely to be subjected, and from thence gradually tapering to the centre of the bridge, where the strain would necessarily be small compared with that at the piers. The roadway is suspended by rods inclined at angles varying in magnitude from the abutments to the middle of the bridge, where the inclination and strain upon the rods attain their lowest value, instead of, as in the old system, hanging vertically from the main suspending chains The Victoria Bridge at Bath, erected in 1836 150ft. in span, was the first constructed on this principle, and several specimens can be seen in Regent's Park at the present time. The largest suspension bridge in the old world is that at Fribourg, which is asserted to be 880ft. in span. The Niagara Railway Bridge is 820ft. from centre to centre of towers. To render a suspension bridge as stiff and rigid as a girder bridge has for some time engaged the attention of the profession. Various improvements have been suggested to maintain the true catenary or curve of a strain and thus reduce the undulation arising from flexibility. Longitudinally a bridge is flexible in regard to the chain and roadway, and becomes slightly altered in its outline whenever a heavier moving load is passing over one end than at the other, or the same may arise from excessive pressure of wind above or below. In the bridge over the Thames at Lambeth, the wire-rope curved chain is braced down to the platform by diagonal ties and vertical struts. This structure has been much condemned by architects, but it is the cheapest bridge built across the Thames. It is however, to be regretted that the material in the towers was not disposed of and arranged in a more artistic manner. A similar arrangement has been carried out in a foot bridge over the main at Frankfort, where the girder is hinged at centre of span. Another plan, adopted in a railway bridge at Vienna, has been to employ two chains placed one over the other, and braced together by diagonal bracing, or to connect the two points of the curved chain most likely to effect any alteration in form by short straight chains with the base of towers. The latest improvement in this direction is Mr. Ordish's rigid suspension principle, consisting of a combination of inclined straight chains retained in position by curved chains, and forming as inflexible a system as possible for maintain-

ing the platform and moving loads. The load on the curved chain being always the same, the curve is retained under all circumstances of loading without variation. The fixed load is supported by inclined straight chains, which are maintained in straight lines by vertical rods suspended from the curved chain. These chains also sustain the moving load, and being thus arranged require nothing extra, such as bracing, to prevent any kind of deformation in the event of the structure being unequally loaded. Direct tensile strains only are induced by the distributed loads and conveyed by these straight chains to the abutments without disturbing the stable equilibrium of the structure.

Deflection is common to all bridges, of whatever construction, and arises from the elasticity of the material employed. With the exception of deflection, Mr. Ordish's rigid suspension-bridge has been found to be theoretically and practically rigid. The main or parapet girders are continuous in the centre span. The principle may well be adapted for sites where a single span only is required, or where two river-piers as in the case of the Francis Joseph Suspension Bridge (opened in 1868), over the river Moldau, at Prague, the ratio of the length of the centre opening to the side spans being such that, in the event of one or both side-spans being loaded while the centre span is unloaded, the weight of the structure in the centre opening shall balance the total weight of the structure and load on the adjoining spans. The proportion will of necessity vary with the total length and weight of the requirements of any bridge. In the case of the Prague Bridge the proportion is about 3 : 1 to satisfy the conditions of unequal loading. The bridge is 820ft. long by 31ft. wide. The centre span between centre of towers is 492ft. The wrought-iron parapet-girders are continuous from end to end, due allowance being made for expansion and contraction, and are supported by means of straight inclined steel chains at distances of 82ft. apart, which are retained in position by a light curved chain. The only deflection arises from the elasticity of the material, and is independent of any unequal loading, as in former suspension bridges. The inclined chains are a fixed unchangeable load, and can have no tendency to alter the form of the curved chain when once suspended in their proper positions. The cost of bridges on this principle does not exceed that of ordinary suspension bridges, which embraces the principle longitudinal stiffening-girders, combined with curved chains, and possesses the advantage of being more adapted to railway traffic, and capable of sustaining the greater partial loadings at various speeds to which a railway bridge is subject. Roebling has obtained a similar effect in his large American bridges by straight inclined chains connected with the girder at the most dangerous points, and extending to the saddle at the top of towers ; many of these structures are employed for railway traffic. In 1862 Mr. Ordish designed a bridge of 82ft. span for a proposed railway over the Thames near the Tower. The design met with approbation of Mr. W. H. Barlow, who considered the principle applicable to spans of 1,100ft. In 1863 the new Albert Bridge was designed upon the same principle, and this is now in course of construction. Shortly after the passing of the Act, the works were commenced, but remained in abeyance for some time, until the line of the new Chelsea Embankment had been arranged, so that a better connection with the shore might be made than exists on the Surrey side of Lambeth Bridge. In the mean time designs were submitted by a few other engineers upon different principles, among which was an exceedingly novel one by Captain Roberts, who proposed to abandon the suspension principle, and span the river by ropes composed of strands of wire (covered over with a selvage of ¼in., enveloping each rope, to prevent oxidation) passing over two pairs of cylinders between the abutments. It is not difficult to prove that a cord or rope stretched straight between two fixed points would bear no very great transverse strain without breaking, supposing the cord to be inextensible, and not to have an infinite longitudinal resistance, and that it would be impossible to draw the rope into a horizontal position, since every material cord or wire, being composed of particles, possesses weight, and would be acted on by the natural force of gravity. Our contemporary, *Engineering*, recomended Captain Roberts to study the involuntary verse in Dr. Whewell's "Mechanics" :

> "There is no power, however great,
> Can stretch a cord, however fine,
> Into a horizontal line,
> That shall be accurately straight."

THE ECONOMY OF THE BLAST FURNACE.

BY PROF. FRED. PRIME, JR.

Transactions of American Institute of Mining Engineers.

To an association like the one before which I read this paper, few questions can be more important and constantly recurring than the following, viz: "What economy can be effected in the manufacture of American iron?" And it is the one with which I purpose to deal in this paper; premising, however, that my object is merely to indicate the direction in which an answer should be sought for, rather than to give it myself. This subject may be divided into two parts, "Economy in the production of pig-iron," and "Economy in the manufacture of wrought-iron;" but it is to the former alone that I shall confine myself this evening.

Of late years the improvements inaugurated in the Cleveland District have excited the wonder and admiration of the iron world. Instead of 30, 40 and 50 feet furnaces, the iron-masters of this district have taught us to build them of 70 and 80 feet, which last height is, I believe, the greatest yet reached in the United States.

The first object of the furnace manager is, *cæteris paribus*, to obtain the greatest amount of metal with the least consumption of fuel. So long as gases are ecaping from the furnace-throat of such a nature and temperature as to be capable of reducing the ore being treated, we know that heat, or in other words, fuel is lost. The first point to be settled is, at what temperature each ore commences to be reduced.

Bell has shown that in the Cleveland ore this process begins at 424 deg. Fahr., while he holds that, in general, sesquioxide of iron is deoxidized at all temperatures between 302 deg. Fahr. and a bright red heat, but that it is never absolutely complete. And he shows that the reduction of ores containing sesquioxide of iron is dependent not on their chemical composition, but on their molecular condition, and the rapidity of the current of gases passing over them, and the deoxidation and carbon deposition are at a maximum at about the temperature of melting zinc, 783 deg. Fahr. Now, to ascertain at what temperature the various magnetites, hematites, and limonites of this country commence to be reduced it would be necessary to make a series of experiments on the subject with native ores, in the performance of which no very great expense would be incurred. This having been done, the next step should be to ascertain the temperature and composition of the escaping gases, in order to see whether all the work that was practicable had been performed by them in the way of deoxidizing the ores. This, of course, would vary very much with the different coals and varieties of each. Should it be found, for example, that the gases when escaping at the furnace-throat were still capable of deoxidizing the ore, then the inference would justly be that the furnace was not high enough, and that fuel was being lost, and it would be a commercial question, as I. Lowthian Bell states it, whether the additional expense of enlarging the furnaces would be sufficiently paid for by an improvement of the operation or an increase of work effected. Where anthracite is used in the blast-furnace, there need be comparatively but little apprehension of the burden crushing the coal, except by the decrepitation of the latter, and I would call the attention of those persons present who direct such furnaces to the question, whether they have ever instituted comparisons in regard to the economy of anthracite furnaces when both the pressure and amount of blast are increased? Anthracite, although equal to coke as a fuel in the amount of carbon, requires a much greater pressure of blast for its perfect combustion, which should be equally distributed through a large number of tuyeres, and I would suggest that iron-masters should endeavor to ascertain the fact, whether with such a dense fuel, considerable economy might not be attained by increasing the height rather than the diameter of such furnaces. We have in this country many open burning coals, which either do not coke at all, or else afford a very tender coke in ordinary ovens. In Great Britain the Ferrie self-coking blast-furnace has been introduced for the purpose of coking the fuel in the furnaces, and at the same time relieving the coke of a portion of its burden. In order to do this a furnace eighty-three feet high is divided, for a distance of twenty feet below the space required for the cup and cone, into four

compartments, by vertical walls supported on arches and radiating from the centre. Both these and the circumferential walls are pierced with flues, so that a portion of the gases taken from the top can be led down to the level of the bottom of the compartments and—receiving a supply of air through gratings in the external wall of the furnace—be ignited and consumed in the flues traversing the partition walls and surrounding the compartments, the draft through these flues being assisted by chimney-stacks at the top of the furnace. Time does not permit me to give any further details, for which I must refer you to "Engineering" of June 16th, 1871, and Volume I of "Journal of Iron and Steel Institute." Suffice it to say, that in Lanarkshire district, the extraordinary result was obtained of saving a ton of coal to the ton of iron made, and also about 2½ cwt. of ore. I. Lowthian Bell, who at first attributed the entire saving to the increased height of the furnace, subsequently changed his opinion and acknowledged that a portion of it was due to the combustion of the gases in the chambers.

Another point to which I wish to direct your attention is the manner of taking off the blast-furnace gases from the top of the furnace. It is a well-known fact that the gases have a tendency to escape up the sides of the furnace, leaving, in the centre, a column of ore, fuel, and limestone untouched. The common method practiced in this country, where the furnaces are close-topped, of taking off the waste gases at the throat from the sides of the furnaces, tends to increase this difficulty by creating a draught in the direction of the sides. Consequently if the gases are taken off from the centre of the furnace above the charging hole, this tendency is more or less counteracted. There can, however, be no doubt that taking off the waste gases from the centre of furnaces tends to prevent the latter from scaffolding, and also to economize fuel. Lurman's patent cinder-tap is probably so well known to you all that mention of it here would be superflous, although experiments at various iron-works have been made with very contradictory results.

Another point, which I cannot too urgently set before you, is the very insufficient attention paid in this country to the proper comminution of ores. When small and large pieces of ores are thrown indiscriminately into the top of a furnace, it must necessarily work very irregularly, owing to the fact that the smaller portions are reduced and carbonized before the interior of the larger ones has begun to be reduced. The consequence of this is a very irregular yield in the different qualities of iron. This would to a great extent be ameliorated, if not entirely prevented, by bringing the ore to a nearly equal state of division by passing it through some ore-crusher or breaking it with hammers. As regards the calcining of ores, but very little has been done in the United States. It is true that in some places black-band is calcined in open heaps, in order to increase the percentage of iron, while in others, as at Johnstown, coal-slack is intermingled with the impure carbonate of iron on a hillside, and the mass of ore roasted. But the important advantage of rendering the magnetites and red hematites of this country porous, and consequently more easily reduced in the blast-furnace by calcining them in kilns, has, I believe, only been tried at Ringwood, N. J., with what results I do not know; but it is claimed for the Westman furnace, which is the kind built there, and is heated by a portion of the blast-furnace gases, that it renders ores porous, however dense they may be. Of course where the ores contain water a great advantage is gained in thus removing it before it passes into the blast-furnace, where heat is rendered latent by its conversion into steam, causing a decrease of temperature in the upper portion of the furnace, or necessitating the use of more fuel. In many furnaces it would be possible to utilize a portion of the gases now lost in roasting the ores. Of course it is a purely commercial question whether the roasting of the ores would pay, but I am convinced that in many localities it could be profitably done, especially by using coal-slack for this purpose. Experiments in this direction will undoubtedly be made before long, and and if coal-slack cannot be directly used, as in the case of anthracite, some method will be devised for converting it into carbonic oxide outside of the calcining-kiln, and, if necessary, a certain proportion of lump coal may be added to the ore in the interior of the kiln. By running the calcined ore, while still hot, to the top of the furnace and passing it into the furnace, the decrease in temperature which always takes place when a fresh charge of cold ore and flux is added, would in a great measure be obviated.

Another point to which I wish to allude is the proper construction of hot-blast stoves. Mr. Bell believes that a very high temperature of blast is not requisite, and that when a temperature of 900° to 1000° Fahr. has been obtained, the maximum has been reached. But Durham coke and Cleveland ore are diffierent from anthracite coal and magnetite or hematite, and it seems to me that we have no right to assume *à priori*, that the conditions which are to be the best in the Cleveland district will also be the most suitable for the fuels and ores of the United States. I believe that by increasing the temperature of the blast considerably above that actually attained in this country, we shall effect a very palpable saving in the amount of fuel now necessary to produce a ton of pig metal, the temperature to which the blast may be heated being necessarily limited by the power of resistance offered by the iron pipes. The very common practice here, of permitting the hot gases to rise up vertically between the limbs of the U-shaped pipes, is a very imperfect method of heating the blast, the gases escaping so rapidly as to be capable of but very imperfectly communicating their heat to the iron pipes, and consequently to the blast. Leaving out of the question the application of the regenerative system as too expensive for us to experiment upon, until the English iron-masters are able to give us some satisfactory answer, let us look at our present pipes, and instead of conducting the hot gases vertically, cause them to pass in a horizontal direction, and we shall find that considerable economy will in all probability be attained; the blast will be heated to a higher degree, and consequently less fuel will be consumed. Should the hot products of combustion be found to still contain useful heat after passing once laterally through the hot-blast ovens, they might be made to return in the direction whence they came, through another oven, or be passed under the boilers. A considerable economy in fuel may be effected by simply arranging the blast-pipes in such a manner that the circles of fusion created by each shall be merely tangential and not intersecting. This may be ascertained by inserting an iron rod through each blast-pipe in succession for a minute, and when that portion of it situated in the circle of fusion is red-hot, the alteration then necessary in the position of the tuyeres is easily accomplished by calculating the space occupied by each circle. The last point to which I wish to allude this evening is the importance of consolidation. Those of you who are acquainted with the British iron trade are probably aware of the enormous capital employed, and the large number of furnaces owned by separate companies—eight being a very common number, and less than four a rarity. This is one of the means by which they can afford to undersell the American iron-masters when we have no tariff. Another advantage they possess is in the consolidation of their works, which enables them to dispense with a large number of officials otherwise necessary.

My aim in this paper has been merely to indicate what might be done as regards economy in the manufacture of iron, although some of the ideas appear to be impracticable at present; but before entering upon any experiments, the first and principal question to be asked and satisfactorily answered is: Will the alteration of the furnaces, and other expenses therein involved, *pay* in the end?

TRANSFORMATION OF IRON INTO STEEL.

By M. Boussingault.

From "Iron."

Iron is transformed into steel by cementing it in charcoal. The process is well known; and I shall merely mention that the metal, in bars of one to two centimetres thickness, is stratified with powdered charcoal in fire-brick boxes having a capacity of 4.9 mc. Two boxes, in one furnace, contain about 27,000 kilogrammes of iron and 3500 kilogrammes of brasque. A cementation (reckoning heating and cooling) lasts about a month. On coming out of the boxes the iron is found altered in appearance and constitution. Its surface is covered with vesicles or blisters, varying in number and size. It has lost its granular or fibrous structure, its characteristic bluish tint, its

tenacity. "Blistered steel," as it is called, is hard and brittle; its grain gives a yellowish or grey reflection, more or less deep according to the degree of carburation. When the carburation reaches a maximum the steel presents, on fracture, an undulated arrangement, with the whiteness and brightness of silver.

I have endeavored (continues the author in the *Comptes Rendus*) to determine the nature and the quantity of the substances acquired or lost by the metal during cementation. I found the task no easy one; and I devoted a considerable time to examination of various processes for determining the various elements which enter (often in extremely small proportion) into the composition of bar iron and steel. The great difficulty was to determine the iron with a precision equal to that attainable with carbon and silicium. I succeeded in estimating the iron to nearly 1-10th or 2-10ths of a millimetre, by M. Marguerite's volumetric method; on the condition, however, of employing, to determine the oxidation of one gramme of metal, a solution of permanganate of potash sufficiently dilute to occupy a volume of 340 to 350 cubic centimetres; 1-10th of a cubic centimetre thus showing the presence of 2-10ths to 3-10ths of a milligramme of iron.

First Experiment.—Two pieces (Nos. 1 and 2) were cut from a bar of iron from puddling of cast metal obtained with wood charcoal, by treatment of a mixture of spathic iron and hematite, from the mines of Ria (Eastern Pyrenees). After scouring, they were introduced into a cementing box, No. 1 into the part that would probably be least hot; No. 2 into the hottest part. After cementation the bars showed the usual protuberances, the surface between these presenting a multitude of small points, visible only with the microscope. The whole surface was coated with a uniform fine pellicle of graphite. The following is a *résumé* of the experiment:—

Ria Iron.	Weight of Bar.	Iron.	Carbon.	Silicium.	Sulphur.	Phosphorus.	Manganese.	Undetermined substances.
	gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.
Bar No. 1.								
Before cementation..	4949.55	4905.00	5.84	5.20	0.59	4.95	10.99	16.98
After " ..	4994 20	4904.30	49.69	5.34	0.30	6.24	10.99	1 .33
Difference.....	+44.65	−0.70	+43.85	+0.14	−0.29	+1.29	0.00	+0.35
Bar No. 2.								
Before cementation	5124 00	5077.88	6.05	5.38	0.62	5.12	11.27	17.57
After " ..	5199.60	5077.41	78.62	6.24	0.26	6.76	11.33	18.98
Difference	+75.60	−0 4	+72.57	+0.86	−0.36	+1.64	+0.03	+1.41

In both cases the increase of weight experienced by the bars exceeded the weight of carbon fixed. The silicium, phosphorus, and undetermined substances acquired, weighed more than the iron and sulphur eliminated.

Second Experiment.—(With Swedish Iron).—A fragment of bar bearing the mark L was placed in the cementing box after scouring. This iron, considered as of excellent quality, had a very fine grain. After cementation I counted thirty-five pretty large blisters, and there were numerous small vesicles, hardly visible to the naked eye. The interior presented on section was silver white. The following is the *résumé* of the experiment:—

Swedish Iron.	Weight of Bar.	Iron.	Carbon.	Silicium.	Sulphur.	Phosphorus.	Manganese.	Undetermined substances.
	gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.
Before cementation..	2000.45	1989.45	6.00	0.32	0.30	1.14	1.80	1.44
After " ..	2026.22	1989.14	32.01	0.61	0.10	1.32	1.42	1.62
Difference	+25.77	−0.31	+26.01	+0.29	+0.20	−0.18	−0 38	+0.18

The increase in weight of the bar was a little inferior to the weight of carbon fixed.

One might ask whether the small differences given in these *résumés* did not arise from errors of analyses, which, while small, are necessarily multiplied by large numbers; the results of determinations made with a few grammes being, in fact, applied to bars of metal of 1 to 5 kilogrammes? Without doubt, we can understand how the iron, independently of carbon, takes, in being cemented, some silicium and phosphorus which have pre-existed in the ashes of the wood charcoal, that it parts with sulphur, and traces of arsenic which escape determination; but it would seem that in a cemented bar one must find all the iron that it contained before its cementation, inasmuch as it does not appear in what state that metal could be eliminated. Still, in all three observations, there was a loss of iron, very slight, indeed, but constant.

For the iron of Ria No. 1 it was about.....0.00014
For the iron of Ria No 2 it was about.....0.00008
For the iron of Sweden it was about 0.00016

To annihilate, or at least attenuate, the influence of errors of analyses, and especially to decide if, really, some iron might be expelled, it was resolved to determine, first of all, the carbon in the whole of the pure iron to be cemented, and then, after having ascertained the increase of weight, to search for that metal in the cement. As regards carbon, the error committed would no longer be amplified; but it was necessary to operate with small quantities of iron, an inconvenience remedied by use of a balance showing 1-10th of a milligramme.

Cementation of Pure Iron.—The iron, tested by the most delicate researches, was shown to be quite pure. The metal had been melted in a porcelain tube, traversed by a current of purified hydrogen gas, then drawn out in wire. A spiral of wire was cemented, during four hours, at a bright cherry red, in powdered wood charcoal, previously calcined. After cementation, the iron was slightly graphitic at the surface, which presented no blisters. The grain showed small brilliant facets.

	Gr.
Pure iron	1.6878
After cementation	1.7111
Increase	0.0233
In the whole cemented spiral was found.	
Combined carbon	0.0223
Graphite	0.0008
	0.0231

The increase of weight from cementation exceeded by 0 0002 gr. the carbon fixed. This difference is probably due to some substances from the charcoal ashes, so far, at least, as it does not result from the very small quantity of iron eliminated. Several experiments showed, indeed, that the ash of charcoal cement acquires a little iron; the original iron has often been doubled. It is probable that the iron is removed in the state of chloride, there being alkaline chlorides in the charcoal. The fact is, that on mixing a little marine salt with the cement, the ashes left by the charcoal then contain a considerable proportion of iron.

Elimination of Sulphur During Cementation.—It will be seen from the *résumés* given above, that the iron lost more than half the sulphur it contained before cementation. Analyses made in my laboratory prove that this elimination is constantly produced. During the fusion of blistered steel to obtain cast steel, the elimination continues. This is how cast steel of good quality contains no sulphur, or very little of it. M. Boussingault proves this from various analyses. Thus it appears that the steels considered of superior quality are really formed of iron and carbon. They are generally free from phosphorus, and the manganese, like the silicium, occurs in a proportion rarely exceeding 1-1000th.

HEAVY LOCOMOTIVES.

From "The Engineer."

In our impression for Feb. 9th, 1872, will be found an article describing an experiment carried out with a Fairlie engine on the South Yorkshire Railway on what is known as the Dropping Well incline. We shall not recapitulate the particulars of that trial. It will suffice to say that the engine, with four 15in. cylinders 22in. stroke, pushed a train weighing 371 tons before it up inclines of 1 in 32 and 1 in 50, and round S curves of as little as 7 chains radius. We refer to the experiment here because the actual work done represented at the time one of the great-

est performances of a powerful locomotive, and as such it affords an excellent example of the maximum duty to be obtained from an essentially heavy type of engine. Why we use the words "essentially heavy" we shall explain presently. Great as the performance of this engine was, it has been nearly, though not quite, equalled by a still larger Fairlie engine, constructed by the Yorkshire Engine Company for the Mexican Railway. This engine, called the Hidalgo, has four cylinders 17in. in diameter and 20in. stroke, with twelve wheels arranged in two bogies, and coupled in groups of six. The total heating surface is 1729 square feet; the grate surface is 29 square feet; the water-tank holds 2000 gallons, and the coal bunkers 30 cwt. of coal, while crates for wood are provided possessing a capacity of 400 cubic feet. The total weight of the engine in running order is 62 tons, and the tractive force at the rails is, with a mean cylinder pressure of 90 lbs., 21,940 lbs., and with 100 lbs., 24,200 lbs. Thus every pound of pressure on each square inch of piston represents 242 lbs. of tractive force, the wheels being 3ft. 6in. in diameter. On Thursday last this engine was tested on the Dropping Well incline. She pushed before her a train consisting of twenty loaded coal trucks, three vans, and one composite carriage; about fifty passengers were disposed on the engine and in different parts of the train. The whole estimated load was 326 tons. Half-way up, owing to the slippery state of the rails, the pressure of steam fell to 110 lbs., and the train came to a stand. In eight minutes the pressure rose to 140 lbs., and with this pressure the engine started the train on an incline of 1 in 26 and on a curve of 7 chains radius. Later in the day two wagons, representing a load of 26 tons, were taken off, and with the remaining load of just 300 tons the engine traversed the whole distance from Lanes-lane Station to the Dropping Well Colliery, a distance of $2\frac{1}{4}$ miles, in $9\frac{1}{2}$ minutes, or at the rate of about 14 miles an hour. The engine, we may add, is fitted with the Westinghouse brake, which served to control the speed of the train down the incline very effectually.

We may now proceed to analyze this great performance, and to deduce one or two conclusions. It will be well to state that we were unable, although invited, to be present at the trial, and the figures we have put before our readers are those which have been published in a daily contemporary, and as their accuracy has not been impeached by the Yorkshire Engine Company we must accept them as official. The moment we proceed to sift them, however, we encounter a very serious difficulty, the nature of which may be explained very briefly. Let the facts be carefully borne in mind. The Hidalgo is stated to have stopped on an incline of 1 in 26. with a gross load of 326 tons, and 110 lbs. of steam. This could not well have represented more than 90 lbs. average cylinder pressure, or a tractive effort, on the showing of the builders, of, say 22,000 lbs. But the gross load—that is, the weight of the engine and train—was say 730,000 lbs. Therefore the traction effort of the engine was only $\frac{730}{22} = 33.18$, or, in other words, one thirty-third of the whole weight of the train. The engine came to a stand, as a matter of course, on an incline of one in 26, where the resistance of gravity alone equalled one twenty-sixth of the gross load. When the pressure was raised 30 lbs. she proceeded. This represented an additional cylinder pressure of, say, 30lbs., or one-third more than was available with 110 lbs. steam. The tractive force of the engine was consequently for the time something like 29,000, and $\frac{730}{29} = 25$. That is to say, the maximum tractive effort the engine could exert equalled one twenty-fifth of the weight of the train, which stood on an incline of 1 in 26, sharply curved. It is hardly conceivable that under these circumstances the engine could have moved the train at all, even if we make no allowance for the friction of a perfectly new engine, which must have been something like 20 lbs. a ton, or 1240 lbs. We have the friction of the train to deal with, which, considering the nature of the curve on which it stood, could not have been less than 4 lbs. a ton at any conceivable velocity, or, say, 1350 lbs. to add to the resistance proper to gravity. The only solution of the difficulty is found in the assumption either that the incline was not so steep as it is said to be, or that the load was not so great, or that the steam power carried was more like 160 lbs. than 140 lbs. per square inch. We shall

not attempt to decide which assumption is correct; but we may point out that the particulars supplied to us at the trial in February, 1872, over the same line, make mention of no incline steeper than one in 32, and a pressure of 140 lbs. then sufficed to take 370 tons up the road. We content ourselves with putting before our readers the only deductions than can be legitimately drawn from the reports concerning the experiment before us, and we wish it to be understood that we have no desire to depreciate the performance of the engine. We simply discharge our duty when we point out that certain discrepancies exist between the reported circumstances of an experiment and the facts, to which we are led up by a very simple chain of reasoning.

We may now proceed a step further, and examine the adhesional power of the Hidalgo. The wheels carry as nearly as may be a load of five tons each, a little more when the tanks are full, and a good deal less when they are nearly empty—for 2000 gallons of water weigh 20,000 lbs., or a little less than nine tons. The tractive effort required to impel a train weighing 326 tons up one in twenty-six was, as we have seen, at least 29,000 lbs., or very nearly thirteen tons. But the engine when standing on an incline of one in twenty-six, lost one twenty-sixth of its weight. What remained for adhesion was not sixty-two tons but less than sixty tons; and as the tanks were probably not quite full, we may say, fifty-nine tons, and $\frac{59}{13}$ =4.53. Thus the coefficient of adhesion of the engine really exceeded one-fifth of the entire insistant weight on the rails, and was in all probability more nearly one-fourth of the insistant weight. This was, of course, in a great measure due to the copious use of sand. But the fact nevertheless goes far to answer an argument that we have often heard urged, to the effect that with loads as small as five tons per wheel the coefficient of adhesion is never equal to one-fifth of the insistant load. Taken for all in all, it will be seen that after every deduction has been made, the trial was very satisfactory, and we may regard it as establishing in some sense a precedent on which we may argue with confidence. Thus it may be taken as proved that with an engine weighing, with coal and water, sixty-two tons, a tractive force of thirteen tons can probably be maintained for a run of $2\frac{1}{4}$ miles; whether it could be maintained for greater distances it is impossible on the data before us to say with confidence. It is to be regretted that in carrying out such trials no attempt is made to measure the consumption of water. It is true that when the engine slips much, the results obtained would be inaccurate and unfair to the engine; but in the second run with the Hidalgo, to which we have referred, no slipping took place, and it would not have been difficult with a little management to get the consumption of water on the run.

The Yorkshire Engine Company have now in hand a very large number of Fairlie engines for different foreign railways. We do not intend to plunge deeply into a discussion which raged fiercely enough some years since as to the merits and demerits of the Fairlie system, but there are some questions connected with these engines which are very interesting, and should not be passed over in silence. We have stated the Fairlie type of engine is essentially a heavy type, and for this reason: The power of an engine resides in the boiler; and no matter what cylinder power we provide, unless the boiler is able to make steam the cylinder capacity is useless. Now, as compared with other types of locomotive, the Fairlie engine is essentially heavy as regards its gross weight per square foot of heating surface. We do not say that other locomotives are not as heavy; but in the case of the double boiler double bogie engine it is apparently impossible to get a small coefficient of weight per square foot of heating surface, whereas in the case of other types of engine the matter lies almost exclusively in the hands of the designer. The Hidalgo has 1729 square feet of heating surface, and weighs full sixty-two tons. If we deduct twelve tons for water and tanks, we have left fifty tons, or, say, 34.5 square feet of heating surface per ton. But the Iron Duke type of broad gauge engine weighed thirty-eight tons, and had 2000 square feet of surface, or fifty-two square feet per ton; and there is not, so far as we are aware, any reason to think that the heating surface in the one engine is more efficient than in the other. Unfortunately no one seems to know exactly how much heating surface an engine ought to have. There are, however, certain well-recognized proportions, rather undefinable, it is true, but still useful as a

guide, and these proportions are certainly not adhered to by Mr. Fairlie. Thus, it will be seen that the Hidalgo is really the equivalent of two tank engines weighing thirty-one tons each, and having 17 in. cylinders, 20in. stroke. This is rather an unusual proportion, and we may put them as 15¼in. cylinders, 24in. stroke. This, however, is a smaller cylinder than will be usually found in tank engines weighing thirty-one tons. Passing this by, it will be found that in practice a tank engine such as we speak of would have about 1000 square feet of heating surface and fourteen square feet of grate. Half the Hidalgo, however, contains only 14½ square feet of grate, and 864½ square feet of heating surface. We do not assert that this is not enough, but we do assert that if it is, we in ordinary practice provide too much; and it would be wise to increase the distance between our tubes, and to use fewer of them.

Another point suggested by the performance of the Hidalgo is the advisability or not of using locomotives of excessive power. We know little of the nature of the traffic the Hidalgo is to work, or of the road she has to traverse, except that she has to get over inclines of one in twenty-five. The question to be solved is simply whether two thirty-ton engines, say on the Fairlie system, would not do the work better than one sixty-ton engine. There must be some limit beyond which it is not advisable to extend the power of a locomotive. What this limit is has never been defined, nor can we find that it has ever been properly discussed. On crowded lines it is obvious that it may be of the last importance to haul very large trains; but on lines of but little traffic, such as exist in general in new countries, it appears to us that in many instances it would be advisable to run two trains instead of one, using a locomotive of half the weight and power required when large trains are adopted. What are the conditions under which one system is better than the other? The point is well worth consideration, and we shall probably return to it.

WATER SUPPLY OF ANCIENT CITIES.

By Lieut. McHardy.

From the Papers of the Royal Engineers.

In ancient times the water was always allowed to flow of its own accord from a high source to the reservoir, along a channel prepared for it called an aqueduct.

Aqueducts existed at a very early date indeed. Among the first mentioned was one erected by Solomon, to convey water from Bethlehem to Jreusalem. It was similar in construction to much more recent works, the conduit being three feet square, and built of freestone, strongly cemented, and coated one inch thick with plaster. The stones were 15 inches thick.

But the system of aqueducts never reached such perfection as it was carried to in Rome. There vast sums of money were expended on these great public works, and their ruins show that they had been executed in a style of corresponding magnificence.

The first Roman aqueduct was constructed about the year 442 B. C. by the Censor Appius Claudius, whose name it bore. Its total length was about 12 miles.

Another was commenced 40 years after this, which brought the waters of the river Anio to Rome, and the expense of the work was defrayed from the spoils taken in the war with Pyrrhus.

Thus, then, were aqueducts from time to time constructed until, in the time of Nerva, A. D. 96, their number had increased to nine, and before the seat of government was removed from Rome to Constantinople there were about 20 altogether.

The management of these works was intrusted to a public officer, and the position he held was considered very important indeed, the office of *Præfectus Aquarum* was only bestowed on those of the highest rank, who had served the State well, and distinguished themselves in war.

As the principle observed in the design of the aqueducts were the same for all, it may be well to consider for a short time the mode of their construction.

From the inlet at the source until the water was delivered in Rome, the stream

was conducted along a closed channel or specus, having a regular and uniform slope or fall toward the city.

The inclination given by the Romans varied from $\frac{1}{200}$ (Vit.) to $\frac{1}{400}$, being much greater than that generally allowed at the present time ; but this may have been necessary for the better scouring of the specus and for preventing any deposit of mud or silt.

In order to maintain the channel at the proper levels it had sometimes to be raised on an earthern embankment, or carried on a series of arches, and sometimes sunk underground and tunnelled through rock.

Embankment was employed when the culvert was slightly above the level of the ground, but when valleys had to be crossed the channel ran on the top of lines of arches. When the level was very much above that of the ground, a second or third tier of arches was built on the lowest series, and the specus laid on top of all.

Our notions of Roman waterworks are apt to be exclusively associated with these gigantic erections, but they supported only a small portion of the total length of the specus. Thus, we find that in the time of Frontinus, A. D. 96, the total length of all the aqueducts was about 278 miles, and of these 28 only were supported on arches. By far the largest part of the channels was below the surface of the ground, for of the 278 miles we find that 243 were underground work.

However, the vastness of the conception, and the great energy in execution displayed in the construction of these lines of arches, give them deservedly a prominent place in our consideration of the Roman aqueducts.

The specus were generally made with rectangular section, or with three sides of a rectangle and an arched roof.

They varied in size from 4 feet high by 2 feet wide, to six feet high by 4 feet 3 inches wide.

It will be allowed that this section for an aqueduct is not well suited for keeping the channel clear of deposit, but the great velocity at which the water must have flowed would have tended to counteract this.

The specus were built of stone or brick, except when they were tunnelled through rock, in which case a brick lining was considered unnecessary. In order to make the culvert water-tight it was coated carefully on the inside with plaster laid on in separate layers. The tunnelled parts of the line seem to have been coated with plaster equally with the parts having the brick lining. The plaster which Pliny declares was found to be the best, was composed of fresh lime slaked with wine, and rubbed with hogs lard and the juice of figs. This was rather a strange composition for a plaster ; never likely to be used in this country. However I have made a little of it for an experiment, and find that the plaster is very much inferior, on the whole, to cements made now on a far cheaper plan ; but the surface becomes very hard and resists water well.

It is natural to suppose that a large quantity of air would be drawn into these channels by the flow of the water ; so, to prevent any serious consequences from the air thus becoming accumulated and compressed in the specus, holes were made which communicated with the open air, and presented a ready escape for the compressed air in the interior. These openings were placed about 130 feet apart along the aqueduct.

When the water had been brought to within about seven miles of Rome, it flowed into a settling pond or piscina. The piscina consisted of a large covered space in which the water might spread out ; and thus, having lost its velocity, the mud in suspension would be deposited, and the clear water would enter the continuation of the specus on the other side. The covering consisted of a series of arches, forming long vaults, transverse to the line of the aqueduct. The passages for water from vault to vault, were so arranged as to be in echellon, so that the water was checked as much as possible in its passage through the piscina. In some piscinæ the water passed through four vaults, which were so arranged that two were on a level with the specus, and contiguous, while the other two were immediately under the first two. The water flowed from one on the top into that below it, and from this passed into the other low vault, rising out of it into the one above, when it again entered the specus.

The works were all coated with cement, which remains in many cases intact at the present day.

When the aqueducts approached the gates of Rome great care seems to have been bestowed on the decorative building of the arches, especially when crossing any of the main roads.

The specus delivered the water at last into a castellum, or service reservoir, from

which proceeded pipes to the public baths, private houses, or public fountains through the town. Some of the pipes emitted water on the spot to those who chose to come for it, and were in fact large public fountains.

The name of the castellum may have been given to these reservoirs from the fact that several similar buildings were erected along the course of the aqueduct, in which resided the soldiers who had to guard the works, and the masons who kept them in repair.

The bulk of the people of Rome carried the water from the public fountains, while the higher class had service pipes laid from the castellum to their own cisterns. The quantity of water allowed was regulated by an officer at the castellum, who by means of cocks could stop the supply at pleasure. The pipes in which the water was distributed through the town were made of lead or earthenware. The leaden pipes had a section somewhat oval and pointed on the top. They were not soldered, but simply pressed together, and it is just possible that the old Romans knew that two clear surfaces of lead when pressed firmly together, unite securely and form a perfect joint.

They certainly had the same dread of the solvent action of soft water on lead which exists at the present day. Vitruvius recommended earthenware pipes on this very ground, because "water conducted through earthern pipes is more wholesome than through lead; indeed" he says," that conveyed through lead must be injurious to the human system." Their earthenware pipes had generally a diameter of about two inches and were tongued into one another in the manner shown in the sketch. In order to strengthen the joints, which were sometimes subjected to a pressure of 200 feet, and therefore were liable to give way, the Romans enclosed them in an envelope of mortar, made with pounded brick, which set so firmly as to make the joints the strongest parts of the pipe.

One other point let us notice—that the Romans never brought the water to the light until it was to be used; and on this account they must have had it free from animal and vegetable impurities, which so readily appear in water exposed to the sun's rays.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The Committee to whom was referred the communications of Professor Estavan A. Fuertes, asking the "Societies to declare what should be the course of instruction in schools and colleges for students of engineering" respectfully presents the following report:

While the Committee fully appreciates the importance of the subject, yet we are of the opinion that the Society is not an advisory body in such matters. Even in regard to professional subjects it guards itself by declaring "that the Society is not responsible for the opinions expressed by its members," and much less would society action on matters pertaining to institutions of learning be considered binding or even advisory. The nearest practical approach to such a position would be the securing of a discussion upon the subject, in which each member would be free to express his opinion, and leave the educator free to draw inferences therefrom.

It is impossible for any body of men to outline a course of instruction which would generally be considered "best," independently of the circumstance which induced them to establish it; and as the circumstances are constantly changing, so courses of study change, in order to be considered "up to the times." In our opinion, the institutions of learning should be left free to construct their courses, and no attempt should be made to mould these after a fixed pattern. The differences which exist between them will then be put to a practical test, and, as they will naturally watch the progress of each other, as well as profit by the criticisms of men in active life, we think that this will in the end lead to the best practical results.

Should this report end at this point, some might infer that we are indifferent to the subject of technical education, and are willing to commit the Society to such a position. On the contrary, we are decided supporters of it, and think that the Society must be, since, on defining the qualifications for membership, it declares "a diploma from any collegiate institution in good standing conferring the degree of C. E. shall be considered equivalent to two years service."

Without disparaging the functions of this Society, it is our opinion that schools of engineering have done more to elevate the standard of the engineering profession than any other single agency. All that pertains to theory and all the classified, practical sciences can and should be taught in the schools. There will always be a practical difficulty in determining the extent to which the details of construction should be taught. It is evidently absurd for the schools to attempt to make experts in any branch of the profession; but this is not a sufficient reason for not teaching, so far as possible, all the *principles* which pertain to practical operations; such as field-work, shop practice, office-work, &c.

The subjects which are intended more especially to promote "board culture" as popularly understood, are not necessary parts of a professional course; they naturally precede technical courses. The system of technical education in this country—if it can be called a system—has peculiarities which have grown out of the circumstances surrounding it. Nearly all the technical schools here devote one or two years to general science and literature—which are no more technical than the old and more purely classical courses. These years are properly preparatory to those which follow. Had we a general system of education, as thoroughly graded as that in Germany, the technical schools would not necessarily

be burdened with this preparatory work; but all things considered, we doubt not but that more thorough work has been done by the system which generally prevails here than would have been by confining the instruction to professional subjects. We ought not to import a foreign system, but seek to build one here especially adapted to our times and circumstances. Our schools ought not to graduate men with a mere "smattering" of the sciences they are to use, but the instruction should be thorough and the standard of graduation high. If an error is made in either direction, the schools should be *too* theoretical rather than *too* practical. The former gives a solid basis upon which to build the professional structure.

It makes but little difference what degree is conferred at graduation; but if that of "Bachelor of Engineering" instead of "Civil Engineer" on the ground that the latter implies a certain amount of practical experience, then we respectfully submit that the latter should be conferred only by a body of practical engineers; such for instance as this Society. In the sense, however, that the candidate has acquired a thorough knowledge of the "Science of Engineering," we see no impropriety in conferring the latter at graduation. The student can become a "Master of Engineering" only by long and varied experience.

Those who desire information upon this subject are referred to the following works.

Report upon Technical Education to the Institution of Engineers, England, made by a committee of that body. London, 1870.

Report of the U. S. Commissioner, J. W. Hoyt, on Education in Europe and America. Washington, 1870.

Report of the Committee of the Trustees of the Rensselaer Polytechnic Institute. Troy, 1870.

Respectfully submitted.

DE VOLSON WOOD,
Chairman.

AMERICAN INSTITUTE OF MINING ENGINEERS. FOURTH ANNUAL MEETING, ST. LOUIS, May 27, 1874.

The papers read at the four sessions are enumerated below.

1. On a Safety Plummet Lamp. By E. B. Coxe.
2. On the Pancake Coal of Nevada. By A. J. Brown.
3. On the Occurrence of Antimony in Arkansas. By Prof. C. P. Williams.
4. On a New Coal-Cutting Machine. By J. S. Alexander.
5. Hydro-Geology. By Prof. P. Frazer, Jr.
6. Experiments with Iron and Steel Rails. By Prof. T. Egleston.
7. Occurrence of Lead Ores in Missouri. By J. R. Gage.
8. On the Volumetric Estimation of Zinc by Metallic Silver. By A. Steitz.
9. On the Condition of Carbon in White and Gray Iron. By Dr. Thomas M. Drown.
10. A New Barometer for Measurements of Altitudes. By Prof. P. Frazer. Jr.
11. On the Mechanical Preparation of Anthracite. By R. P. Rothwell.
12. On Rock Drilling. By E. G. Spilsbury.
13. Wastes at American Smelting Works. By A. Eilers.
14. On the Mechanical Analysis of Rocks. By Prof. T. Egleston.
15. Some Experiments in Coking Coals under Pressure. By Prof. E. T. Cox.
16. Arkansas Semi-Anthracite Coal. By Prof. W. B. Potter.
17. The Zinc Process at Carondelet. By John W. Pack.
18. Deep Boring with the Diamond Drill—Supplementary Paper. By Oswald J. Heinrich.
19. Method of taking the Horizontal Section of a Blast Furnace. By F. Firmstone.

SOCIETY OF ENGINEERS OF CALIFORNIA. The above society has held its first ordinary meeting at the Third District Court Room, Mechanics' Institute, San Francisco, when the following interesting papers were read:—"On Boiler Pressure," and "On the Calculation of Earthwork." The following papers were announced as being in preparation:—"On Compound Engines," "On Quartz Mining Machinery," "On the Mechanical Condensation of Vapors, and "On Sea Diving. Mr. J. E. Smedburg, of the Gas Office, San Francisco, is the secretary.

IRON AND STEEL NOTES.

ALLOYS OF IRON.—A new process for the manufacture of alloys of iron with manganese, tungsten, titanium, or with silicon, has recently been brought forward by La Compagnie des fonderies et forges de Terre-Noir, La Voulte et Bességes, which will be found described, with drawings of the special blast furnace used, in the Chronique de l'Industrie, 1873, vol. II., p. 235.

This system consists in mixing cast or wrought iron or steel previously brought to a fine state of division, such as filings, turnings, pulverized iron sponge or granulated iron with ores of manganese, tungsten, or titanium separately or together, or with quartz also, in a state of fine division, and in such proportion as will furnish the desired alloy. When this mixture is moistened throughout with an ammoniacal solution, or with slightly acid water, and compressed into balls by the hand or in an iron mould, heat is developed, and after some hours when the mould is opened, it will be found to have aggregated to a compact and hard mass requiring blows of a hammer to break it into fragments, which will stand a red heat and not begin to break up until almost at their point of fusion. By treating these blocks or fragments in a suitable furnace at a very high temperature, alloys of iron, containing from 25 up to 75 per cent. manganese, silicides of iron, containing up to 22 per cent. silicon or alloys of iron with tungsten and titanium, or triple alloys of these different metals, may be obtained. The furnace employed is a small cupola, the shaft of which is made of the best of firebricks, and rest upon a cast-iron bearing ring, supported by four pillars, so that the whole of the lower part of the furnace may be removed when required for repairs; between the lowest part of the shaft, which is conical, and the crucible or hearth of fusion, is an intermediate part, also conical, recommended to be made of lime, magnesia or pure alumina, encased in a sheet iron conical casing, supported or hung from the bearing ring previously alluded to, and

below this the movable crucible, which is simply pressed or held up to meet the conical part by means of wedges below it, so as to be easily disconnected for repairs, as it is very strongly attacked during the operation. The crucible itself is formed of lime magnesia, or also of a solid piece of carbon, made by mixing powdered graphite, gas coke or other pure coke, with tar, and then baking the whole at a low red heat for some hours until it forms a compact hard mass, free from cracks or fissures. At the top of the crucible, a single tuyere lets in the blast, which should be heated at least to 670° Fahrenheit, and have a pressure of some 5 or 6 inches of mercury. A patent, No. 1,574, dated May 1, 1873, by A. Browne, London, being a communication entitled "Furnace for the Manufacture of Metallic Alloys," appears to embody all the features of the above process.

As a substitute for and as an improvement upon cast steel, M. Levallois, of Paris, has patented in France the employment of three new alloys of iron, with tungsten and nickel, which can be worked like ordinary steel, and are said to be very hard. The three alloys contain the respective metals in the following percentage proportions:—No. 1, soft iron 93 parts, tungsten 6½ parts, and nickel ½ part: No. 2, soft iron 95 parts, tungsten 4½ parts, and nickel ½ part; and No 8, soft iron 97 parts, tungsten 2½ parts, and nickel ½ part. The crucibles and furnaces employed are similar to those ordinarily used in melting cast steel, but a special flux is made use of, which is composed of 36 parts boracic acid, 32 parts calcined quartz, and 32 parts washed carbonate of lime; all of these substances, after having been powdered and mixed, being melted together in a crucible, poured out upon an iron plate, and the solidified mass broken into small fragments. When making the alloy, the tungsten and nickel are first placed in a tube of soft iron, with about 1 per cent. of the flux, and this tube is placed in the middle of the rest of the iron in the crucible, which is itself covered with from one-half to 2 per cent. of the same flux. When the whole is melted it is poured as usual into moulds of sand or metal.—Chronique de l'Industrie, vol. 2, p. 170, 1873.—*Journal of the Iron and Steel Institute.*

DEFINITION OF THE TERM STEEL.—In the Memorial du XXV Anniversaire of the Association of Engineers of the School of Arts, Manufactures, and Mines of Liége, published this autum at Liège, M. Adolphe Gruner, the head of the steel department of the Société John Cockerill, at Seraing, communicates a note on the "Definition of Steel." This gentleman had previously, in 1869, defined the term steel as including all malleable products of iron industry, obtained from a state of fusion, in contradistinction to the term iron, which he reserved for all malleable products which have not undergone absolute fusion; although this definition has been accepted by Professor Jordan, and other writers on siderurgy, it clashes somewhat with our old views, to find that under this sytem, our long-known cementation, or blister steel, must be regarded but as carbureted iron, while fused iron, containing none, or but a trace of carbon, must be classified as steel. The two series of products, *i. e.*, the irons and steels, are classified by M. Gruner as follows:—

Percentage of Carbon.			
0 to 0.15p.c.	0.15 to 45p.c.	0.45 to 0.55 p.c.	0.55 to 1.50p.c. or more.
Series of Irons.			
Ordinary Irons.	Granula Irons	Steely Irons or Puddled Steels.	Cemented Steels. Styrian Steels.
Series of the Steels.			
Extra soft Steels.	Soft Steels	Half soft Steels.	Hard Steels.

RAILWAY NOTES.

LIGHT AND ECONOMIC TRAMWAYS.—Reference was made in the *Mining Journal* of April 25 to an improved method of transport without breaking bulk on mixed-gauge railways, invented by Mr. JOHN WALKER, of James street, Old street, and the patents having now been completed some further details of the invention can be given. The first object of the invention is to make the top surface of the rail as low as possible to the ballast, to prevent the wheels from jarring the sleepers or bottom frame of the railway. To accomplish this each sleeper is notched out by four circular saws from 2in. to 3in. deep, and to the exact gauge required for the railway. These notches or grooves cut across the sleepers are to receive the rails, and may be so made as to fit down tight, or have space for a wedge on the outside. The rail is formed of one piece of timber in the centre, and an iron plate on each side, and is called the composite rail. The timber may be 3½in. deep by 1½ in. thick, and the two plates of iron 3½in. deep by ¼in. or 3-16 in. thick; these plates are either rivetted or screwed together on the timber, taking care that no joint of iron or timber rests upon the same sleeper. In this way we have a continuous rail without a but joint, which not only makes a strong rail but also the most pleasant to travel on, having just enough elasticity to secure that purpose. By placing the rails into the sleeper instead of on the top, they form in themselves a complete frame independent of spikes or screws to whatever length they may be carried, and as each sleeper is exactly alike, the rails will also be perfectly true, so that the wheels of the engine may fit exactly, instead of oscillating from side to side, doing more damage to the rails than the weight of the engine.

For general traffic the head of the rail is formed either of angle-iron or a steel cap, bolted through the rail with bolts and nuts, care being taken that the joint is not over any other joints of the rail; in this way when the cap wears out it is easily renewed without disturbing the framework of the rails, and at a very small cost, and great saving in labor and materials, thus rendering this invention of the greatest importance for branch lines, and also wherever railways are required to open up new countries, when the cost would, it is estimated, amount to about one-half that of the present system. From a series of carefully conducted experiments made by Mr. David Kirkaldy, it appears that taking the centre between the sleepers, a rail 3½in. deep is equal to 9 tons; 4½ in. deep, 14 tons and 5 in. deep 18 tons. There would, of course, be a great saving of freight when exported, and in laying down a line in the cost of labor and time, there being no chairs, fish-plates, trenails, &c., required. For the construction of light and cheap lines for bringing down ore, &c., from mines in sparsely populated districts the system appears well worthy of attention.

RUSSIAN RAILWAYS.—The combined receipt of all the Russian lines amounted in December

to 11,914, 829 roubles, against 8,601,863 roubles in December, 1872, showing an increase in the closing month of 1873 of 38⅔ per cent. The aggregate receipts of all the Russian lines in 1873 were 122,877,263 roubles, as compared with 101,-973,836 roubles in 1867. The average receipts per verst worked presented an increase in 1873 as compared with 1872, of 10.80 per cent. Nearly one-third of the traffic comprised in last year's revenue passed over the Great Russian Railway.

ENGINEERING STRUCTURES.

THE MERSEY TUNNEL.—We have from time to time referred to the project for constructing a tunnel under the Mersey at Liverpool, which owing to the navigation of the river, is the only possible way to connect the Lancashire and Cheshire shores.

Some time ago a shaft was sunk on the Birkenhead side of the Mersey, in order to ascertain the nature of the rock, and the borings have been driven for a distance of about 250 yards westward of the river. The result of this examination was of the most satisfactory character. The stone was found to lie in horizontal strata, and to be of the most homogeneous character, and without flaws through which the water might penetrate; but, in order to render the tunnel perfectly dry, it will be lined with brick and cement, The *Liverpool Mercury* says the sinking of the shaft on the Liverpool side will be commenced almost immediately, and those who understand the nature of the contemplated works believe that they will be carried out without any difficulty. The works have been jointly planned by Mr. John Fowler, C. E., and Mr. James Brunlees, C. E., and they are under the immediate superintendence of Mr. William Morton as resident engineer.

Parliamentary powers for the formation of this tunnel have already been obtained, but there has been a departure from the original scheme, and a new company has been formed, not only for the carrying out of the work, but for certain important contemplated extensions of the line on the Liverpool side of the river. According to the original scheme, it was intended to carry the Liverpool end of the tunnel into a capacious station to be erected near Compton House, and also to unite the railway with the service of the Cheshire Lines Committee in Ranelagh street. This, however, has for the present been abandoned; and according to the amended plans, the tunnel, when completed, will terminate at a central passenger station which it is proposed to erect near Hatton Garden, between Victoria Street and Crosshall Street. From this station a line for goods' traffic will curve towards the west beneath Vauxhall Road, and down towards the Waterloo Road and the Prince's Half-tide-Dock, emerging from the tunnel on a level with the dock railway, which will be connected with a large goods' station to be erected between Great Howard Street and the Waterloo Road.

The new station to be constructed near Hatton Garden will be 25 feet below the surface; but arrangements will be made for an approach from the street for cabs, so that the necessity for lifts, such as were once contemplated, will be entirely obviated. Descending by a gradual incline from Dale street, the tunnel proper under the Mersey will be reached—or rather it should be said the two tunnels, for the up and down lines will be in separate excavations, each cut out of the red sandstone rock, with a pier or support of solid rock, 15 feet in thickness between them. The length of the submarine portion of the tunnel, from shaft to shaft, will be about 1,200 yards, the breadth 25 feet; and the height, from the rail level to the underneath surface of the arch, will be 17 feet; the whole lying about 25 feet below the bed of the river. On emerging from the tunnel at Birkenhead the line will be so constructed as to form a junction with the Great Western Railway not far from Green Lane. It is believed that as soon as the works referred to are carried out the Cheshire Lines Company will seek a revival of their powers, and obtain authority to effect a junction by a line, chiefly underground, with the new station in Dale street, starting near St. Andrew's Church, thence beneath Great Charlotte street and St. John's Market to Dale street. When these works are carried out, the Midland, the Great Northern, the Sheffield and Lincolnshire, and the Great Western Railway, with its network of lines, will be in union, thus opening direct communication between some of the most important districts of the kingdom. Under no circumstances can the tunnel be formed in less than three years; and should unexpected engineering difficulties arise the task will occupy even a much longer period. —*Architect*.

THE CHENAB RIVER BRIDGE is in progress of of construction at the establishment of Messrs. Westwood & Baillie. This structure is intended to carry one of the Indian state railways across the river Chenab in the Punjab; it has an aggregate length of over 1½ miles, and is composed of sixty-four spans of 142 feet in length, each measuring from centre to centre of the intervening piers. Each girder, or rather each pair of corresponding girders constituting a span, is independent and discontinuous, so that any vibration or oscillation communicated by the passage of a rolling load over any one span is confined for the time being solely to that span, and produces no effect upon the remaining spans in the structure. Each girder has a depth of 9.174 feet, measured from centre to centre of the vertical plates in the upper and lower flanges respectively, and the total depth from out to out is 1 foot more. The flanges are of the ordinary trough shape, built up of vertical plates, one series of horizontal plates, and connecting angle irons. These last we noticed are single, that is riveted to only the outside of the vertical plates at their junction with the horizontal ones. This is similar to the arrangement adhered to in the flanges of the Charing Cross bridge. It does not form by any means so good and advantageous an attachment as is effected by the use of double angle irons riveted to the vertical plates on both sides. The variation in the sectional area of the flanges is made partly by decreasing the depth of the vertical plates and partly by differences in the number and thicknesses of the horizontal plates. An important point to be kept in view with regard to the employment of deep vertical plates in the flanges of girders is that they directly tend to reduce one of the most important elements of strength in the depth.

The Chenab girders are of the Warren type, and are built with a camber. The web consists of

one series of triangles, the bars of which are inclined at an angle of 60 deg. with the horizontal. A pair of diagonals meeting at each apex, are connected to the flanges at intervals of about every ten feet. Each diagonal is composed of four angle irons with cross bracing between each pair, in the place of the cross section of the girder. No pins are used, as might be expected from the character of the design, but all the connections are formed by rivets. Strong gusset plates are riveted at the intersections of the diagonal bars of the flanges. These are absolutely necessary in order to provide against the great local strain arising from the concentration of the weights at those points. The cross girders are placed about five feet apart, one at each side of the lower apices of the equilateral triangles of the web, and the platform of the bridge is formed of buckled plates made on the premises, and riveted to the cross girders. There are no rail-bearers, as the metals rest close down upon the platform. The bridge has a single line of rails, and is intended also for the passage of ordinary wheeled vehicles, cattle and foot-passengers. At certain intervals some of the spaces are widened so as to serve as a refuge while trains are passing. It was suggested by one of the visitors, not so incongruously as might at first sight appear, that the lower flange of the main girders would answer exceedingly well as a drinking trough for cattle. The workmanship of the bridge, which was well shown in a pair of girders erected on the ground, constituting a complete span with cross girders and platform, gave great satisfaction to the visitors, nearly all of whom were competent judges of such matters.

In addition to the Chenab girders, and among others of a smaller description, Messrs. Westwood & Baillie have in hand some for one of the Government railways in Japan, a country which certainly does not intend to be behind the age with respect to steam communication inland. There appears to be a large amount of unnecessary cutting, bending, and forging in the iron work for these structures. The designer seems to have lost the principle that the nearer any particular section of iron can be kept to the form in which it leaves the rolls the cheaper the workmanship can be done, especially if the iron be in long lengths.

NAVAL AND ORDNANCE.

THE REFFYE FIELD GUN.—One of the most interesting pieces of field artillery in the Vienna Exhibition was the bronze breech-loader invented by Lieutenant-Colonel Reffye, of the French artillery, and mounted for view near the Machinery Hall entrance to the Rotunda.

Already, before the late Franco-Prussian war, the defects of the service field artillery were recognized by the French Government, and experiments on new guns were instituted with the ultimate view of selecting an improved weapon. The only gun which was even partially tried before the war broke out was the Reffye "cannon de 7," which was made at Meudon and experimented on at Versailles in the month of June, 1870.

At the capitulations of Metz and Sedan, the French army lost the greater part of its artillery, and the task of supplying their raw levies with a new weapon which should cope with the Prussian field guns devolved upon the Government of the National Defence. Their choice fell upon the Reffye breech-loader, and before the close of the war over 2,000 of these weapons were manufactured, which rendered good service during the Prussian siege of Paris and the rebellion of the Communists which followed after.

In the beginning of 1873, a series of experiments on guns of this system was carried out at Calais with very satisfactory results. Since then the "cannon de 7" has been adopted definitely as the principal arm of the French field artillery. The gun is made wholly of bronze, its general shape being cylindrical from the breech as far as the trunnion ring, and conical from thence to the swelling at the muzzle.

Its principal dimensions are as follows:

Calibre	85 millimetres...	3.5 inches.
Diameter of powder chamber...		3.642 "
Total length ...	2.01 metres.....	79 214 "
Length of bore ...	1.875 "	73.8 "
Weight of gun ...	640 kilos.....	12.6 cwt.

The bore is rifled with fourteen grooves, having a depth of 1.5 millimetres, and a uniform twist of 5° 44′. The breech-closing arrangement consists of the screw with portions of the thread removed which has been already described in Engineering. When the screw is withdrawn from the breech it rests in a steel ring, let into the end of the gun, and mounted on hinges like a door, so that it can be swung back, thus leaving the passage to the chamber free. The touch-hole is drilled obliquely through the screw in such a position that if the latter be not securely driven home, the mouth of the touch-hole lies hid behind a covering plate fastened to the steel ring, and the charge cannot be ignited. Accidents are thus rendered impossible.

The cartridge case is very remarkable, serving as it does not only to inclose the powder charge, but also to prevent the escape of gas through the breech-screw and touch-hole. It moreover prevents the powder chamber from becoming unduly heated. With these ends in view, the case is made up of three distinct parts, namely:

1. A cup-shaped base of sheet brass, which when the explosion takes place is expanded like a Bramah collar, so as to close completely the touch-hole, and also the lines of contact between the breech-screw and the base of the powder chamber.

2. A cylindrical body of tin-plate, which is covered within by four coils, and without by three coils of paper.

3. A cylinder of strong pasteboard which unites together the cup and the body.

The two last-named parts not only strengthen the cartridge-case, but act also as non-conductors which prevent the chambers from becoming heated, and moreover save it from the erosion due to the action of the powder gases.

The cartridge-case is extracted after each round by a very simple contrivance. The head of the breech-screw is hollowed out so as to form a shallow truncated cone, and in the side of the cone three spiral scores are cut. When the explosion takes place, the cup-shaped base of the cartridge is blown into this hollow cone, and the soft brass is imprinted into the scores so firmly that on the screw being turned round and withdrawn it carries with it the whole case. It would seem at first sight that the metallic body of the

cartridge would expand so tightly against the sides of the chamber as to render the withdrawal impossible. This difficulty, however, is prevented by leaving the seam in the metal cylinder unsoldered, and covering it simply by a metal strip, which of course allows the cylinder to spring without becoming permanently expanded, while the strip, together with the pasteboard and cartridge paper, maintain the case gas-tight.

The ordinary charge consists of five rings of cake powder, formed by compressing common gunpowder till the specific gravity is 1.615. The rings have an internal diameter of 52 millimetres, and are placed one above the other, so as to form a hollow cylinder, the weight of which is 1.130 kilogrammes. The head of the cartridge is occupied by a disc of grease inclosed in a pasteboard cup.

The projectile is a common scored cast-iron shell weighing 6.9 kilogrammes = 15.2 lb., the length being three times the calibre. Originally it was enveloped with a continuous lead jacket to take the rifling. This has now been done away with and two leaden rings substituted. Experiments on the projectile seem, however, still to be pending, and till these are completed it would be useless to go into the matter further.

The Reffye gun has recently been subjected to an exhaustive series of experiments at Calais by a commission of French artillery officers, the results of which have been chronicled in the "Revue d' Artillerie ' by the Chef d' Escadron Mercier, one of the members of the commission.

The following are some of the results as regards range, elevation and time of flight, the charge and the projectile being the same as those given above and the initial velocity being 390.3 metres.

Time of Flight.	Angle of Descent.		Angle of Elevation.		Range.
secs	deg.	min.	deg.	min.	
0·53	0	25	0	12	200
1.12	0	56	0	38	400
1.66	1	31	1	7	600
2.28	2	9	1	39	800
2.91	2	51	2	12	1000
3.95	3	34	2	47	1200
4.27	4	19	3	24	1400
4.95	5	5	4	2	1600
5.68	5	53	4	41	1800
6.43	6	41	5	21	2000
7.19	7	33	6	2	2200
8.00	8	26	6	45	2400
8.82	9	21	7	29	2600
9.66	10	16	8	14	2800
10.54	11	20	9	0	3000
11.45	12	27	9	48	3200
12.36	13	40	10	38	3400
13.37	15	0	11	30	3600
14.37	16	29	12	25	3800
15.38	18	8	13	23	4000
16.49	19	58	14	25	4200
17.61	22	3	15	31	4400
18.80	24	23	16	43	4600
20.08	26	59	18	1	4800
21.43	29	51	19	27	5000
22.88	33	5	21	3	5200
24.47	36	40	22	51	5400
26.40	40	35	24	55	5600
28.39	45	1	27	26	5800
30.62	49	5	30	28	6000

These results were considered eminently satisfactory, and as regards accuracy in shooting, the weapon leaves little to be desired.

The breech-loading apparatus, which is tolerably free from complication, worked fairly in the trials, but it is far inferior to the Broadwell cylindro-prismatic wedge.

The metallic cartridge-cases merit favorable mention. As an instance of the value of the latter in saving the chamber from deterioration, it may be mentioned that after a sustained fire, first of 115 and then of 240 rounds, although the muzzle became extremely hot, the breech never exceeded a very moderate temperature, and could always be touched by the hand without the slightest discomfort. Upon the whole, the French Government and Colonel Reffye must be congratulated on having produced results which have never before been attained with any bronze field gun.

WHITWORTH ORDNANCE.—The Committee on Artillery Studies, after nearly two years of consideration of the various system of cannon, have pronounced definitely in favor of the Whitworth rifle cannon as that which, from its material, the processes of manufacture, and the system, most nearly approaches perfection. The committee emphatically condemn the French system of cast-iron strengthened by wrought-iron bands, as unscientific and practically proved inefficient. The Krupp gun, of Krupp cast steel, strengthened with bands, they consider unreliable, notwithstanding its fine material, chiefly owing to the uncertainty and irregularity of effect which, they say, always attend the action of the hammer, however ponderous, on masses of iron. Finally they consider the English Armstrong, Woolwich, and Whitworth cannon much superior, in construction and strength, to the best yet produced on the Continent, the Woolwich an improvement on the Armstrong, and the Whitworth far ahead of either in the essential qualities of a good gun. This superiority of the Whitworth cannon the committee ascribe to the quality of the homogeneous steel used, to the care in its selection, to the oil tempering which it receives, to the use of the hydraulic press instead of the hammer, and to the mode of constructing and connecting the cylinders and other parts of the gun. In relation to the quality of duration, the committee mention that, while the Krupp cannon has an average life of 600 to 800 shots, the Whitworth cannon employed by the Brazilian forces during the Paraguayan war, have averaged 3,500 to 4,000 shots each, without a single case of bursting or serious damage having occurred among them.—*The Brazilian Times.*

BOOK NOTICES.

SANITARY ARRANGEMENTS FOR DWELLINGS, INTENDED FOR THE USE OF OFFICERS OF HEALTH, ARCHITECTS, BUILDERS, AND HOUSEHOLDERS. By WILLIAM EASSIE, C. E., &c. Smith, Elder & Co. 1874. 12mo, clo., $2.75. For sale by D. Van Nostrand.

This volume gives, in a collected form, a series of papers published originally in the *British Medical Journal*. Its object, the author states, is to give "an account of the most ordinary sanitary defects in dwelling-houses and public institutions, in respect to drainage, water-supply, ventilation,

warming, and lighting;" and "to set forth," what he believes "the most simple and effective means of *preventing* or *remedying* such defects." He thinks it necessary to say further:—"The purpose of this small work is to point out, in the plainest language, what ought to be done to render ancient and modern houses healthy. I will eschew all extraneous matter, as much as possible, and will not fall into the common practice, better honored in the breach than the observance, of heading the chapters, or interlarding the matter with lines from the poets." It is but due to the author to say that he has faithfully avoided this tendency "to drop into poetry" on the subject of house-drains, sewers, &c.; on the plainness of the language, however, we cannot speak very highly. Many householders, it is to be feared, will find some difficuly in recognizing an S-shaped pipe under the name of a "sigmoid"; or in appreciating the beauty of a description in which the overflow sewage from a cesspool is said to "debouch into the fields"

The greater part of the book is occupied with a description of the various sanitary appliances for buildings which have from time to time been proposed, or which have been brought into actual use; such as drain-pipes, of which twenty-two different kinds are figured and described; traps, of which thirty-six are given; fire-grates and stoves, &c. In many places, indeed, it reminds us of nothing so much as a manufacturer's or tradesman's catalogue. On the whole, however, this work contains much useful information and many excellent suggestions. On the subject of house-drainage, we are glad to see that Mr. Eassie has adopted and advocates the principle of leading all house-drains into one collecting drain, outside the house if possible, and placing in this main drain an efficient trap, properly ventilated so as to prevent any of the sewer gases finding their way into the house through the drains or pipes.—*Nature.*

MATERIEL DES CHEMINS DE FER DE FAIBLE TRAFIC ET TRAMWAYS A VAPEUR.—Par AMEDEE SEBILLOT (Paris). This is a pamphlet on rolling stock for small railways and steam tramways, which is now attracting much attention in France. The object, of course, is to produce economy in industrial and other branch lines; or, to put the case in the author's own terms, lines to be executed of which the receipts cannot be estimated at more than 5,000 to 6,000 francs per kilometre that is to say, £320 to £384 per mile. For such lines, whether laid by the side of roads or otherwise, the conditions of the case will generally necessitate inclines of 0.05 to 0.06. Many instances prove that lines of such profile may be worked with carriages of simple adhesion; but in such cases the ratio between the true load and the dead weight is the cause of considerable expense. On inclines of 0.05 a locomotive cannot draw more than its own weight, which brings the ratio of useful load to only twenty-three per cent. of the total weight set in motion. In such cases the author asks whether it is rational to separate the engine from the carriage. He advocates, in fact, steam-carriages, which he has found to give fifty-three to fifty-six per cent. of useful load, that is to say a reduction of total weight to the amount of fifty per cent., and, of course, this produces great economy in first cost, maintenance, and fuel. M Sébillot finds, by calculation, that the cost per kilometre, which is 5,000 fr. by ordinary trains, would be reduced to 3,000 fr. by steam carriages; and he quotes the success of such carriages in the United States. M. Sébillot has calculated the cost of such steam-carriage of three types:—(1) for passengers and small parties only; (2) mixed; and (3) for goods only; the carriages being provided with a lateral as well as an angular movement of the extreme axles, so as to work readily in courses of twenty metres' radius. In these carriages the effective weight contributing to the adhesion, that of the machinery and framing, may be greatly reduced, while the suppression of the coupling chain and buffer-springs, and the consequent absence of shocks, allows of comparatively light construction. The following are the results arrived at with four types of carriage: (1) passenger and parcel carriage for inclines of 0.03—dead weight, 7,000 kilogs.; effective load, 8,000 kilogs; (2) mixed ditto for same inclines—dead weight, 8,800 kilogs.; effective load, 11,200 kilogs.; (3) passenger and parcels carriages, for inclines of 0.05 to 0.06—dead weight, 9,300 kilogs.; effective load, 10,700 kilogs. (4) goods carriages—dead weight, 12,500 kilogs; effective load, 17,500 kilogs. By adopting a very economical mode of construction, M. Sébillot states that such branch lines may be made at 45,000 per kilometre (£2,880 per mile, or at the roadside for 25,000 fr. (£1,600 per mile), so that lines might be constructed which would only earn from 4,250 fr. to 5,500 fr. per kilometre.

ECLIPSES, PAST AND FUTURE, WITH GENERAL HINTS FOR OBSERVING THE HEAVENS. By the Rev. S. J. JOHNSON. Oxford and London: Parker & Co.

This work, which is as well conceived as it is carried out, contains some most interesting notices of ancient eclipses, and also of the most important during each century of the Christian era up to the present time. A peculiar feature of the book is a list of eclipses of the sun and moon from 1874, October 10, to 1912, April 1; and from 1912, April 17, to 2381, July 21, eclipses of the sun only. Although not very interesting to the present generation, these remote eclipses, predicted to occur within the next 500 years, will acquire a progressive value in the opposite direction to that of ancient eclipses, in affording data for the further correction of the lunar and solar tables, for doubtless, as astronomical science advances, residual phenomena may be found which will throw still further light on the motions of the bodies of the solar system. The second part of Mr. Johnson's work, entitled, "A Cycle of Celestial Objects for a Small Telescope," is arranged on the plan of Webb's "Celestial Objects for Common Telescopes," but is by no means an imitation of that useful book. It contains brief notices of such double stars and nebulæ, amounting to 152, which may be studied with telescopes under four inches of aperture, preceded, as in Webb, by remarks on the bodies of the solar system, the aurora, meteors, &c. In the notices of the planets, the author gives the dates in future years when the most interesting phenomena of each planet may be looked for, and thus his work becomes in a measure ephemerides of eclipses, transits, and occulations for many years to come. In his arti-

cle, "The Earth," the author enumerates some of the most striking phenomena in physical geography, seismology (earthquakes), and meteorology, and under that of the "Moon" he points out the most important lunar formations as they successively come into sight. By the way, the only error we have noticed in the work is in connection with the celebrated spot Linne, which the author places in the Mare Tranquillitatis. It is really, as most of our readers are aware, on the Mare Serenitatis. Under the head of "Meteors," the author alludes to Mr. E. L. Garbett's suggestion that the cities of Sodom and Gomorrah were destroyed by the group of meteors following Tempel's comet of 1866.

We most cordially recommend this work to amateurs who may desire to possess a suitable Companion to "Celestial Objects for Common Telescopes."

THE TRUTH ABOUT SEWAGE IN A FEW WORDS. By Andrew Fenwick. London: W. Isbistern & Co., 1874.

In a few lively and short chapters, Mr. Fenwick places this usually opaque matter in a clear light. Setting out with the postulate that the excreta which are the essential parts of town sewage are only valuable for the ammonia they envelop, he reviews the various sewage solutions proposed and the aspects of sanitation as connected with sewage, and in conclusion shows that the question is one of great complexity, so that a prescription successful under one set of circumstances, may be wholly inapplicable in another. "The flood discharged into the Thames at Crossness bears away," he says, "myriads of tons of potential manure; but that manure is irrecoverable by any process that would not exceed its value manifold. Fortunate is London in having such an outfall. Other towns less favored are bound to do something to avert river pollution; but whatever they do it will cost money, and, in some cases, much money."

ELEMENTS of Metallurgy, a practical treatise on the art of Extracting metals from their Ores. By Arthur Phillips. 8vo, cloth, $15.00. For sale by D. Van Nostrand.

This is a new edition of Phillips' Elements of Metallurgy, forming a large octavo volume, of 750 pages, and nearly 200 engravings. No expense has been spared in carrying out the design of the author, viz: the production of a work which shall present to the student in a concise and practical form, the information at present to be gathered from the perusal of several distinct treatises. The text is elucidated with numerous wood-cuts (many of which have been reduced from working drawings) executed under the superintendence of Mr. W. Welch. The general contents of the work embrace a treatise on fuels and refractory meterials. A description of the principal metalliferous minerals with their geographical distribution. Statistics of the amount of each metal annually produced throughout the world, obtained from official sources or authentic private information, and the methods of assaying the different ores, together with the processes of metallurgical treatment.

EARTHWORK MENSURATION, on the Basis of the Prismoidal Formula; Containing a Simple and Labor-saving Method of Obtaining Prismoidal Contents Directly from End Areas. By Conrad R. Howard, C.E. New York: D. Van Nostrand, 27 Murray and 23 Warren Streets. Price, $1.50.

There is probably nothing to which the civil engineer has more frequently to trace annoying errors in his aggregate estimates than to his many trifling mistakes in calculating the amount of earthwork involved in overcoming the many natural obstacles with which he has to deal, and the tedious nature of the processes hitherto adopted for obtaining the desired results has certainly been some excuse for inaccuracy. Recognizing these facts, Major Howard, C. E., of Richmond, Va, U.S., has prepared a very valuable treatise, the object of which is to enable the practical engineer to calculate the true prismoidal contents of a mass of earth to be removed with the same facility as averaging end areas, and that this object has been attained is acknowledged by some of the most eminent engineers who have already had the opportunity of testing the book. By the employment of only a couple of dozen pages of tables, the calculation of which has, doubtless, involved a considerable amount of labor, Major Howard is enabled to present a new and systematized method of finding the prismoidal contents of earthwork by the use of rules readily understood, and easy of application by any one accustomed to the ordinary business of an engineer's office, the method possessing, moreover, the great advantage that by giving accurate corrections for the familiar approximations in general use the calculator has, as the author very truly remarks, the element of error constantly before him, and must speedily learn by practice, if not by theory, the cases in which such corrections become important.

As all works of this class are valuable or worthless, according as they are reliable, or otherwise, the first inquiry which necessarily suggests itself is whether the author is scientifically correct in the principles which he recommends for adoption, and that there may remain no question upon this point, Major Howard devotes the first 20 pages of his book to the strictly mathematical investigation of those principles in such a manner as to show the derivation of the formulæ to be employed in practice; while the second part contains the necessary instructions for obtaining the prismodial contents sought, and supplies practical rules and examples, showing the uses of the tables in simplifying computations by the formulæ given, so that whether it be required to find the prismoidal contents of thorough-cut or fill when the road-bed widths and side slopes are constant between the end sections; of side-hill work, pyramids, &c., with similar end sections; or of thorough-cut or fill when the end road-bed widths are different; and to make the necessary correction for curvature in single width throughout, or in side-hill work when the transverse surface slope is regular, the requisite calculation can be easily and quickly made. It is pointed out that the rules for computation of cubic contents are based on the condition that the transverse service lines of the end sections shall be sensibly similar, but it is very properly pointed out that by combination they will cover all cases to which the method of "roots and squares," and of "equivalent level heights," can be correctly applied, and that the practical limit of their application may be indefinitely extended by increasing

the proximity of the cross sections in rough ground.

With regard to the tables, Major Howard states that he has calculated them himself, and as the system used was that of continued additions with special tests at intervals, he believes they will be found absolutely correct within the purposed limits, whether the last figure of any amount given be intended to express the nearest whole number or the nearest decimal; and, judging from the results obtained with the rules and tables applied to three or four examples taken indiscriminately, with a view to test them, we do not hesitate to say that they are quite reliable. The work will prove of almost inestimable value to practical men from the vast saving of time that will be effected by its use when estimates of as near as may be perfect accuracy are desirable, and for this reason it is likely to find great favor with the engineering profession. —*London Mining Journal.*

MISCELLANEOUS.

THE ARMOR-PLATED "INFLEXIBLE."—The belief of Admiral Elliott that the days of armor-plating are nearly over, is certainly not justified by this extraordinary vessel. The exact drawings and particulars of her build are very naturally kept from public knowledge, but we may, without any breach of patriotism, give a general conception of the design adopted in this, the youngest of our iron clads. What may be called the distinguishing characteristic of the *Inflexible* is that she will have, in the sense of vulnerability, no "wind and water line" at all, Every one must know that the vitals of a man-o'-war lie along the belt of her flotation—a breach of her sides in that region lets in the sea and swamps her. The *Inflexible* carries all her side armor upon a central space 110 ft. in length. It is 24 in. thick, and protects with that monstrous wall of solid iron her engines, her crew, and her battery of four 80-ton guns. Along the rest of her—fore and aft —there is no vertical armor, but a thick inside cushion of cork of enormous buoyancy, more than 60 ft. square in section, surounding bunkers full of coal for the supply of the ship. A horizontal deck of thick metal extending fore and aft from the citadel, at a depth of 6 to 7 ft. from the water line, will cut off all this unarmored upper portion from the real hold of the vessel. Thus if the enemy should send shot or shell through every coal bunker and corner of the *Inflexible*, forward and aft, letting in the water everywhere, he could only – if the design answers expectation – lower her a single foot in the sea. Her citadel, it may be confidently expected, he could not pierce; at any rate with guns at present in use. In a word, the constructors of the *Inflexible* give an enemy the upper slices of the ship, except her citadel, to do as he likes with; and it is by making the ends floatable under any circumstances that the iron work of the ponderous citadel, with its turrets and freeboard, can be carried. The ram and the torpedo are therefore the only perils which threaten this forth-coming fighting ship; but perhaps these also might be provided against if her bottom under the water deck were constructed in many compartments. Enough, however, has been already hinted about our newest behemoth to show that, whatever her success, the age of armor-plating is not ended yet.—*London Telegraph.*

THE BESSEMER SALOON STEAMER.—This vessel, intended to obviate sea-sickness in the passage across the Channel, is rapidly approaching completion. The vessel has become completely plated, and the fitting of her engines and boilers in place will soon be accomplished. This work will be done while the ship is on the stocks, so that when she is launched she may by the same tide be sent upon her trial trip. The vessel, so novel in her construction, is an object of great interest, and scarcely a day passes without several visitors from a distance inspecting her. The ship is 350ft. long at the water-line, and for 48ft. at each end, the deck is only about 4ft. above the line of flotation, so that in rough weather the sea will wash over these low ends. The decks on this portion of the vessel have a considerable curve and the sides of the ship are rounded off so that the water may escape as speedily as possible. This form of end has been selected with a view to obviate any tendency to pitching. Above these low decks a breastwork is erected about 8ft high. It is 254ft. long and all the width of the vessel. The whole of this breastwork deck is to be devoted for the use of the passengers, and that portion fore and aft of the paddle-boxes will be protected with staunchions. The vessel will be propelled by four paddle-wheels, and 90ft. of the space between the paddles will be occupied by the swinging saloon. Beyond this at each end is occupied, nearest the saloon by the engines, and next by the boilers. At one end of the breastwork there will be accommodation for the crew of the ship, and beneath their quarters stowage room for passengers' luggage, &c. At the opposite end of the breastwork the space is fitted with cabins for the special use of ladies, and below these cabins there is a saloon 51ft. long, and fitted with sofa seats all round. Along the sides of the breastwork deck, between the paddle boxes, there are other cabins for passengers beside smoke-rooms and refreshment rooms. The Bessemer swinging saloon is making good progress, and already a good idea of the principle may be obtained by an inspection of the work. The saloon proper is about 70ft. long, 26ft. wide, and very lofty. The weight of the saloon is borne by four large bearings, one at each end and two near the centre. The end bearings are fixed on iron transverse bulkheads, which are well stiffened by fore and aft ways to prevent them buckling. The saloon will be one of the most superbly fitted apartments afloat. The top of it will form a promenade deck, and it will be fitted all round with seats. The saloon will be entirely under the control of the machinery invented by Mr. Bessemer, and it is declared that it will be kept perfectly free from rolling during the passage across the Channel, and passengers, it is expected, will not feel any more unpleasant sensation than they would in going up or down the Thames. The ship will be supplied with two very large life rafts on the plan patented by Mr. Christie, and she will be steered and her capstans, &c., will be worked by hydraulic machinery. She was designed by Mr. E. J. Reed, C. B., M. P. —*Times.*

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A PRACTICAL THEORY OF VOUSSOIR ARCHES.

By WM. CAIN, C. E.

Written for Van Nostrand's Magazine.

1. The theory selected, in the following article, is that of Dr. Hermann Scheffler, * which will be quoted from literally in places. A sufficient number of experiments with wooden arches, probably to establish this theory, will also be given.

It is necessary to consider *the principle of the least resistance* in order that the thrust, anywhere in an arch, in direction, position and magnitude, may be located.

The Rev. Canon Mosely is the author of this principle, which has been amplified by Dr. Scheffler in his treatise above alluded to. It may be briefly stated thus :

Principle of the least resistance. Let the external forces which act upon a structure, be combined into one resultant, P ; and let the resisting forces R′, R′′ - - - be each decomposed into components respectively ⊥ and ∥ to the direction of P. Then will the components of R′, R′′ - - - - ⊥ to P be the least that will cause equilibrium, consistently with the physical properties of the body or bodies composing the structure. *For* the sum of the components ∥ to P must equal P ; but the components ⊥ to P are only brought into play from the peculiar disposition of the resisting surfaces of the structure and there is no need for their further increase after they have caused stability.

As M. Fournie observes: This supposes *first*, "that the *molecular* actions, which constitute the reactions, take place without sensible velocity ;" *secondly*, "that the *molecular* actions are developed successively ; so that the system cannot arrive at the position of greatest tensions without having passed through the positions of less tensions. Constructors willingly admit these propositions as plausible. The principle follows immediately."

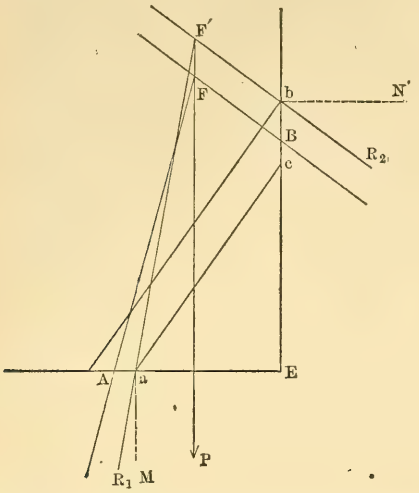
Example. * Let a beam, as in Fig. 1, lean against a horizontal wall at A and a vertical wall at B ; its extremities may slide on those planes, requiring friction to prevent it. The weight P of the beam acts through its centre of gravity, and by the above principle, if the resultant resistances at A and B be decomposed into vertical and horizontal components : the sum of the vertical components=P and the horizontal components must be the smallest that the friction, between the walls and beam, will admit of : hence the directions of the resistances F_1 R_2 and F_1 R_1 must be as near the vertical as possible. But with regard to the physical disposition of the surfaces AE and BE, it

*Detailed in his most excellent German work, a French translation of which by M. Victor Fournie is entitled "Traité de la Stabilité des constructions ; 1re partie, Theorie des Voutes et des Murs de Soutènement." Paris, 1864.

* "Traité de la Stabilité," § 5.

is necessary to equilibrium that the directions of R and R_1 make angles with

FIG. 1.



the normals to BE and AE, at most, equal to the angles of friction ϕ_2, ϕ_1, of the ends of the beam on those planes: hence take $R_2\ b\ N = \phi_2$ which gives the direction of R_2. As the direction of R_1 must intersect that of R_2 on P: we have $F_1\ R_1$ the direction of R_1.

It is evident that for incompressible voussoirs, the force R_2 passes through b and R_1 through a, as this gives the least horizontal thrust; the directions of R_1 and R_2 being more nearly vertical than when they pass throug hany other points, as A and B.

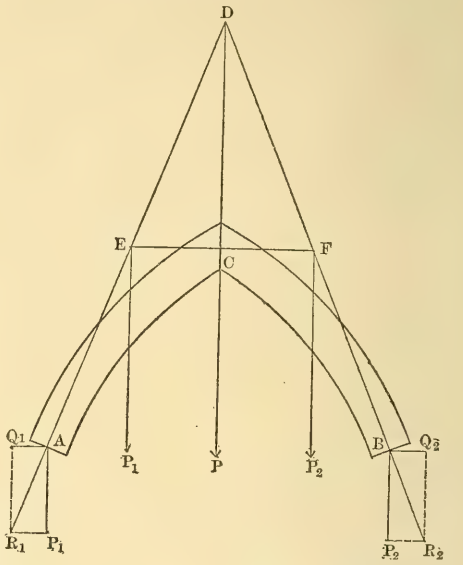
For an elastic, compressible beam; as it will bend as well as compress at the edges, the force R_2 will pass near edge c, and the force R_1 near edge a.

If by the construction above, $R_1\ a\ M$ becomes $> \phi_1$ the beam will fall by sliding. The molecular resistances at A and B act along a portion of the surfaces bc, aA, for compressible beams, though they vary in intensity so that their resultants pass near the edges c and a. For the mere suppositious case of an incompressible beam, the resultants pass through the edges, and hence there is but one molecular force acting on a mathematical point at either b or a. An experimental proof of this theory will be given in Art. 10.

Most writers *assume* the force R_2 as horizontal, which is evidently only the case when there is no friction between the beam and the vertical wall. This is among the untrue hypotheses that are often so confidently stated by learned mathematicians.

SYMMETRICAL ARCHES.

FIG. 2.



2. * "We shall consider first an arch, formed of two branches AC, BC, (Fig. 2), symmetrical and placed in juxtaposition, and comprised between two parallel vertical planes $\perp$ to axis of arch," the arch being right cylindrical. "This arch, composed of voussoirs in the shape of wedges, formed of *incompressible* materials, leans against two abutments at its extremities A and B, and is loaded not only with its own weight but with any other weight whatsoever, distributed symmetrically on either side of the crown C. The mass of the arch is subject to the laws of friction in its joints. The adherence of the mortar, interposed between the voussoirs, being difficult to estimate will not be considered." As the two half arches are symmetrical as to the crown C, it is clear that the points of application, A and B of the reactions R_1 and R_2 of the surfaces of support, will be also symmetrical in relation to the vertical passing through the crown, and that the line AB will be horizontal, in whatsoever manner the points A and B may vary upon the surfaces of support.

* § 8.

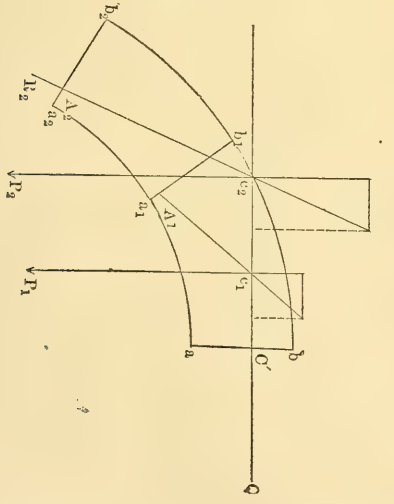
If we decompose the reactions, R_1 and R_2, into their horizontal and vertical components P_1, Q_1, P_2, Q_2, we should have $P_1 = P_2 =$ the weight of half arch with its load, and the thrust $Q_1 = Q_2$, should from the principle of the least resistance be a minimum.

Let us consider now one of the two halves, for example AC. Let EP_1 be the vertical passing through the centre of gravity of this half with its load ; to hold this mass in equilibrium it is necessary that there exist at the crown a force whose direction CE passes through the point of intersection E of the vertical EP_1 with the direction of the reaction R_1.

As the vertical component of R_1 equals the weight P_1 acting through E, we conclude, without difficulty, that the tension at the crown C of the arch is necessarily equal to the second component Q_1, of the reaction R_1 and must be horizontal as it is.

From what precedes we are allowed to consider only a half-arch, leant against a fixed surface at A, and solicited by a horizontal force at C. When there is equilibrium, we shall seek the least value of this horizontal force Q and its point of application at the crown.

FIG. 3.



3. (Fig 3). Let ab, a_1b_1, a_2b_2, be the joints of an arch ; P_1, P_2, the vertical directions of the weights of the parts $ab\ b_1a_1$; $abb_2\ a_2$; including the loads on the parts bb_1, b_1b_2, ... ; P_1,P_2 acting through the centres of gravity of the parts considered. The horizontal force Q combined with the reaction R_2 at the joint a_2b_2 holds the part abb_2a_2 in equilibrium and similarly for the reactions on other joints.

At the points where the direction of Q cuts P_1, P_2, combine those forces with Q, the resultant of Q and P_1 cuts joints a_1b_1 at A_1, which is therefore the *centre of pressure* on that joint. As the weight abb_2a_2 with its load equals P_2 and is the weight on joints $a_2\ b_2$, the resultant of P_2 and Q will give the force acting on a_2b_2 in direction, position and magnitude ; its direction cuts a_2b_2 at A_2, which is therefore the *centre of pressure* on that joint.

In the same way the resultants and centres of pressure on all the joints may be determined. A broken line connecting these *centres of pressure* on the various joints is called by Dr. Scheffler the *line of pressures*. For voussoirs indefinitely small it becomes a curved line.

That granted, in order that the arch may remain in equilibrium, it is necessary :

1. That the points of intersection C', A_1, A_2, fall in the interior of the respective joints ab, a_1b_1, a_2b_2. If for any joint this is not so, *e.g.*, if the point A_1 was above b_1, the mass $abb_1\ a_1$ would then turn around the edge b_1, as an unresisted couple would be formed. To explain : suppose the resultant R_1 to pass outside of joint $a_1\ b_1$; conceive two equal opposed forces, each equal to R_1 to act at edge b_1 ; this does not disturb the equilibrium ; then R_1 the force acting through A_1 (which is outside the joint) with its equal but not directly opposed force at b_1, would form the unresisted couple in question which causes overturning.

2. That the directions c_1A_1, c_2A_2 of the pressures upon the joints do not make angles, with the normals to the respective joints which exceed the angle of friction. If it was not so, sliding at the joints in question would occur of the mass above or below.

However, the friction of the materials usually employed in construction is sufficiently great to not give cause for fear as regards sliding, generally.

It is very easy to alter the direction of the joints should sliding be apprehended, hence it will not be considered further.

It is to be remarked that the foregoing theory does not require horizontal resistance in the spandrel, which is not generally built with the same care that is taken in the construction of the arch stones, and hence

cannot generally be regarded as unyielding; hence when a *line of pressures* such as CA_1A_2 passes, somewhere, out of the arch ring, a serious derangement of the arch may occur, even though the spandrel may prevent its falling: hence it appears to be a poor construction, to build such an arch, in preference to an arch in which the resultant pressures on the joints everywhere keep within the limits of the arch ring. This will be adverted to again.

4. It is necessary to demonstrate a few propositions, to locate the true line of pressures, corresponding to the minimum of the horizontal thrust.

The voussoirs will be considered indefinitely small; hence the line, drawn through the centres of pressure at each joint, will be a curved line, which is probably what it is in real arches, with voussoirs of any size. As before remarked, Dr. Scheffler calls this line, the *line of pressures*.

None of the joints will be supposed to make angles to the left of the vertical, looking upwards, greater than 90°

*(See Fig. 4.) If we vary at will the greatness and point of application of the horizontal force Q at the crown, we obtain curves which mutually cut each other. *But two such curves, which cut each other in any point whatsoever, D, will cut each other only at points situated upon the same horizontal as D; otherwise they will not meet again in any point above or below this horizontal.*

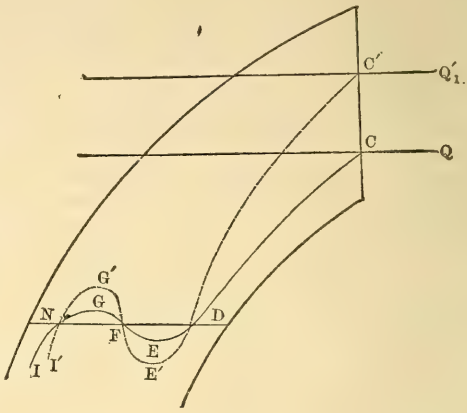
To demonstrate these propositions, let P_1 be the weight which corresponds to the *joint* that the curve of pressures traverses at the point D. Let p_1 = distance of the point D from the vertical through the centre of gravity of the weight P_1.

The moment of P_1 in relation to D is thus P_1p_1. If Q is the horizontal pressure at C and z the depth of the point D below the horizontal through the point C, zQ is the moment of Q as to D; D being a point of the curve of pressures.

We have the characteristic relation, $zQ=P_1p_1$. Let F be another point of the same curve at the *same height* as D. Let P_2, p_2, be the weight and lever arm, corresponding to the point F: $zQ=P_2p_2$ whence $P_1p_1=P_2p_2$.

If now a new curve of pressures is supposed to pass through D; $z_2Q_2=P_2p_2$ and consequently $z_1Q_1=P_2p_2$; hence it passes through F and cuts the first curve on the same horizontal as D_1.

FIG. 4.



Next let there be I, a point of the first curve which is not at the same height as the point D; P_3 the weight on the joint which passes through I; p_3 the distance from I to the vertical through the centre of gravity of this weight and h, the difference of level between I and D. We have for all curves, which pass through these two points.

$$z\,Q = p_1P_1 \text{ and } (h+z)\,Q = p_3P_3$$

whence

$$Q = \frac{p_3P_3 - p_1P_1}{h} \text{ and } z = \frac{p_1P_1h}{p_3P_3 - p_1P_1}$$

according to which, while h has a finite value, Q and z have necessarily *fixed values*, which can correspond but to a single curve of pressures.

Hence two different curves can never cut each other in two points situated at different heights. It may be remarked that isolated weights may produce curves of pressure like either of those drawn in Fig. 4, though such curves are but rarely met with in practice.

The meeting of two curves at G', E, G,—with a horizontal tangent is a contact and not an intersection; as we can consider the contact of the two curves as the coincidence of two points indefinitely near on the same level. For points, such as D, which have no horizontal tangent, the meeting is an intersection and not a contact from the same consideration.

In fact suppose for an instant that the dotted curve has contact only with the first at E. Suppose now the value of Q_1 to diminish from a change in the point of application of the thrust at the abutment.

*p. 34.

From a consideration of Fig. 3 we see that the curve will move down the joint, to the right of E, and hence must cut the first to the right of E and above it. Its other intersections, it has just been shown are at F, N - - at the same level as D, the first point of crossing.

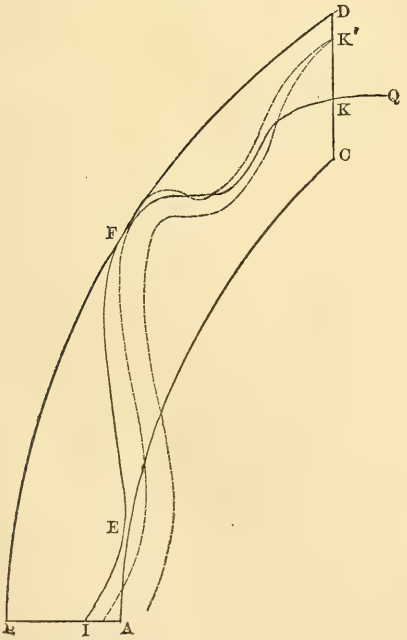
These important propositions being established, the problem before us is the following: Among all the curves of pressure, possible, which lie in the arch ring, find that for which the thrust Q is a minimum, and which by the principle of the least resistance is the only true one.

5. (See Fig. 5.) Proposition :—*When the point F, of contact with the extrados, is higher than the point of contact E, with the intrados, of a curve of pressures; it corresponds to the minimum of the thrust, whether the point E, precedes or follows the point F, going along the curve from the crown to the abutment.*

Fig. 5 represents the last mentioned case, which is the most usual; the other, being very rarely found in practice, will not be demonstrated. The case represented by Fig. 5 is demonstrated as follows:

1. If preserving the point of application K, we augment or diminish the thrust Q, the curve will either go outside of the extrados at F or the intrados at E, and hence will be impossible. This is easily seen from the construction of Fig. 3, where a greater horizontal thrust moves the points A_1, A_2 - - nearer the extrados, a less thrust toward the intrados.

FIG. 5.



2. If preserving the force Q, we raise its points of application towards D, we obtain a new curve, which is entirely above the first, which cuts then the extrados about the point F: it is then impossible. This may also readily be seen by a consideration of Fig. 3. If now we augment Q, the curve will be raised still higher near F and, of course, will go out of the arch ring and thus be less possible.

3. If, however, with the point of application still above K, at K^1 for example, we diminish Q so that the part of the curve near F may become tangent to the extrados, it is necessary that this new curve cuts the first K F E I *somewhere* between F and K. By Art. 4, as F is below K, this intersection may take place in a single point (lower dotted line), or according to the particular form of the curve in an odd number of points on the same horizontal (upper dotted line); so that, in all cases the new curve will be to the right of the first curve between F and the nearest point of intersection, but as below this last point the curve cannot meet again the first, it will remain constantly to the right of it; hence it will cut the intrados near E. It is then impossible. There cannot exist then a curve, under the assumed conditions, meeting the crown joint in a point higher than K.

4. If now we lower the point K without changing Q, the curve will cut the intrados above E, as it must remain below and to the right of the first curve; and for a stronger reason if Q is diminished. But if we increase the value of Q, in this new point of application below K, sufficiently, the curve may remain entirely in the interior of the arch, and generally an indefinite number of curves of pressure can be drawn in the arch. From what precedes, it follows that the curve K F E I, corresponds to the minimum of Q, since for the point K there is only one curve, for a point above K, there cannot exist a curve, and for a lower point, there are only curves corresponding to greater values of Q.

It will frequently happen that F coincides with D, and E with A; in which cases the meeting of the curves with the extrados or the intrados is not necessarily a con-

tact. The preceding demonstrations nevertheless hold.

6. When the point of contact F with the extrados is lower than the point E of the intrados, the curve of pressures corresponds to the maximum of the thrust Q.

It would be foreign to the purpose of this article to demonstrate this; (which is however easily done in the manner just shown; and in the same way the other case of the minimum is easily demonstrated) or to give all the cases where rupture occurs, which Dr. Scheffler has so fully illustrated.

Suffice it to say that the whole theory of curves of pressure is solved by him as simply as artistically. As he remarks: * "An exact knowledge of the actions that are produced in an arch can alone give to the constructor the proper confidence to design the form of an arch, the thickness of the arch, the joints, and the abutments in such a manner as to assure the stability of all the parts; and this is especially true of a new work, where experience and analogy do not furnish the needed information."

Numerous experiments will be given in the sequel, which will be found to agree with this theory, and to establish it practically, taking into consideration the compressibility of the materials used.

7. Before going further, it would be as well, perhaps, to make some remarks about the effects produced by the compressibility of the voussoirs and mortar. As the law of that compressibility is unknown, we can not tell exactly how far from the edges of the joints is the nearest approach of the curve of pressures in an arch. It may be kept in view though that the resultant pressure on any joint, can be exactly at the edge of the joint only for *incompressible voussoirs* that can receive a finite effort upon a mathematical line. For actual bodies, this finite force must be distributed over a finite surface.

Let the molecular reactions, which make up the resultant on each joint, be supposed parallel in direction. Conceive a plane passing through the resultant R (Fig. 6) on any joint, parallel to the intrados at the joint in question.

Call an *elementary resisting force* on one side of this plane f, and its lever arm in relation to that plane l. Likewise call f' and l' an elementary force, and its lever arm on the other side of this plane; then we must always have

$$\Sigma f l = \Sigma f' l'$$

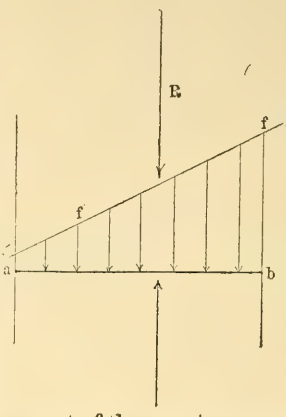


FIG. 6.

It is evident that if at any joint the resultant passes near an edge b, that Σf is much greater than $\Sigma f'$, as the last forces act with greater lever arms; hence in any actual arch the resultant falls back a certain distance from the edge necessarily on account of the greater compression produced at that edge; and this is moreover necessary to prevent crushing, as our materials are not infinitely strong.

For example, in the head of the bridge of Neuilly, the horizontal thrust at the crown on a slice 1ft. in thickness is about 109 tons, supposing the line of pressures to pass through the upper edge of crown joint. In reality it is at a certain distance from this edge, which if we knew as well as Σf between that distance and the edge, we could form a better idea as to whether the surface included was able to bear the thrust. Thus suppose in this case that $\Sigma f = \frac{3}{4}\ 109 = 82$ tons and on such a small surface as we shall find that it is uniformly distributed. If the crushing force of the stone is taken at five tons per sq. in, this would require a bearing surface of $82 \div 5 = 16$ sq. in.; *i.e.* the resultant could pass within 1.33 inches of the edge without causing rupture. Mortar has a much less crushing weight than good granite in blocks, but for a mortar joint only say $\frac{1}{8}$ inch thick, its crushing weight must approach that of some building stones, and probably the resultant could pass within 6 inches of the edge in this bridge without causing rupture. There are reported many cracks in the head of this bridge. It is very probable though that the resultant retreats farther in the arch ring, for swift rolling loads could then too readily crush the edges, as the molecular resistances take time to act and assume their final magnitude, the curve of pressure changing with every rolling load. Again, take the viaduct Fig. 9, which is 50ft. span

* p. 193.

and 10ft. rise; the horizontal thrust on 1ft of thickness is 20 tons, which can be borne on a surface of 4 sq. in. by granite, the mortar requiring the line of pressures to retreat a few inches from the edge. The depth of the voussoirs at the crown in this bridge is 2.5ft.; for the bridge of Neuilly 5.3 feet; we thus see that the resultant *may* pass, proportionally to the depth of the voussoirs, very near the edge without causing crushing, and as on most bridges there is no crushing at the edges, we infer that this resultant must pass a certain distance from the edge in every instance.

The mortar may, besides giving a more intimate, and consequently a greater bearing surface, cause the line of pressures to retreat within the arch ring, thus distributing the thrust a little more uniformly over the joint. Suppose the centre of an arch struck as soon as it is turned, while the mortar is still fresh at the crown; for the usual forms of bridge arches, the mortar will be compressed, and in fact squeezed partially out at the upper edges of the joints near the crown, and this will be the more marked the thicker the joints.

However, as the mortar hardens during the building of the spandrels, the line of pressure will afterwards approach the top of the crown joint as the arch is weighted down, any sinking of the crown being attended with a more intimate contact at the upper bearing surfaces at the crown. This becomes still more evident when we suppose a rolling load on the crown of an arch whose mortar joints have completely set, and likewise consider that the abutments yield slightly.

Shaving off the upper parts of the joints near the crown would tend to counteract this.

Dr. Scheffler thinks that, for good stone, if we can draw a line of pressures, within the arch, that nowhere approaches nearer the edges than $\frac{1}{4}$ depth of joint, that the stability of the arch is assured.

Dr. W. J. M. Rankine gives $\frac{1}{3}$ depth of joint as the nearest approach to the contour curves.

The experiments that will be given show very plainly that the total thrust on a joint, together with its special compressibility, alone locates the true curve of pressures, so that it will depend principally upon the dimensions of the arch and surcharge; for a small arch being very near the edges at the joints of rupture, for a larger arch with a greater thrust, at a greater distance from these edges.

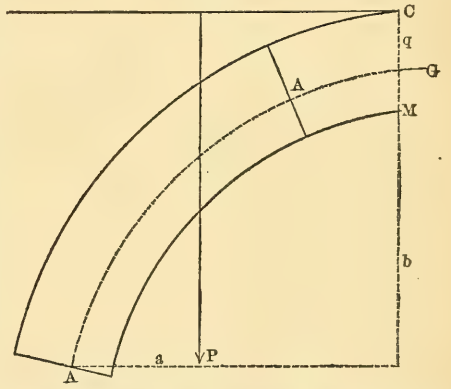
It is a fact, in some existing arches, that the voussoirs at certain points are pressed together near their edges, the joints slightly opening on the other side.

At any rate wherever the engineer locates these circumscribing, limiting curves, to the curve of pressures, the latter must always conform to the minimum of the thrust in the limits chosen.

If no curve of pressure can be drawn in the limits, the depth of the voussoirs must be increased on part or the whole of the arch; or the profile may be altered; or finally we may combine both of these methods to secure stability.

8. Let us consider as in Art. 2 a slice of the arch 1 unit thick. In Fig. 7, let Q= the horizontal thrust (compare Fig. 3 throughout); q, its vertical distance below the apex C; P=weight of an arch and load

FIG. 7.



C A on joint at A; a=horizontal distance from A, the centre of pressure on the joint, to the vertical passing through the centre of gravity, P; h=vertical distance between C and A; b=vertical distance between M, the point of application of Q at the crown, and A.

If we consider another point A′ of the curve of pressures, at a vertical distance above A=e, we shall have an analogous notation P_1, a_1, b_1.

If we know the points M and A, we have

$$a\,P = b\,Q \quad \therefore Q = \frac{a\,P}{b} \quad \ldots\ldots\ldots (1).$$

If we know any two points as A, A′, $a\,P = b\,Q = (b' + e)\,Q$; also $a'\,P' = b'Q'$ hence

$$Q = \frac{a\,P - a'\,P'}{e} \quad \ldots\ldots\ldots (2)$$

$$q = h - \frac{a\,P}{Q} \quad \ldots\ldots\ldots (3)$$

Having obtained from eq. (1) or eqs. (2) and (3), Q and its point of application at the crown, we find where the resultant pressures cut each joint as in Art 3, and if these points are within the proper limits of the arch ring and satisfy the minimum of the thrust, the curve is the true one. From eq. (1) it is evident that Q is smaller as b is greater or a smaller; hence the true curve will pass as near C, and the lowest point of the joint at A as the compressibility of the material will admit of.

If the first curve drawn, passes outside of the prescribed limits in one or more places; take points on the limiting curves opposite the points of maximum departure, and by eqs. (2) and (3), pass a curve through two of these points.

If the arch is stable at all, it will almost invariably be found in practice, that the last curve so drawn will fulfill the required conditions of remaining in the prescribed limits and corresponding to the minimum of the thrust. If not a third approximation may be tried, and so on.

In all the numerous and varied examples that Dr. Scheffler works out, he never resorts to a third trial; and in practice, after becoming familiar with the leading cases, the first trial is generally sufficient, when the limiting curves are assumed, as the writer can testify to from experience. Thus this theory does not demand an unlimited number of gropings as Poucelit asserts,* so as to render the method nearly illusory in practice.

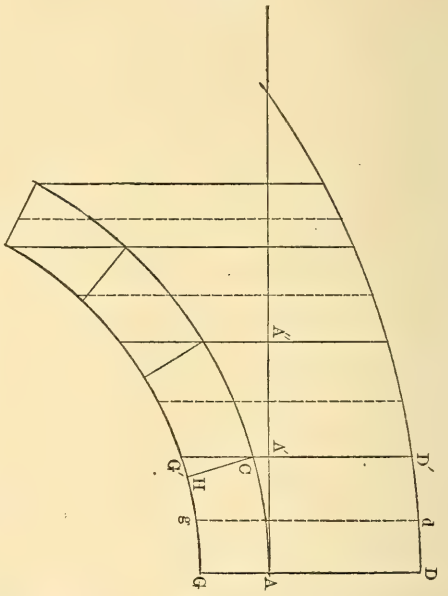
Let us now proceed to show how to find the centres of gravity of the weights abb_1a_1, abb_2a_2, (Fig. 3), as also the magnitudes of those weights. If the arch is loaded with any weights, reduce them to the same specific gravity as that of the masonry of the bridge supposed homogeneous, as follows: Lay down these weights in their exact positions on the arch and alter the vertical dimensions to conform to the specific gravity of the stone. We shall thus substitute blocks of stones, by scale, for the surcharge of earth, water, etc., or the rolling load.

By this means we have the solid contents of abb_1a_1, etc., proportionate to the weights P_1, P_2 - - - and hence can be taken for them.

We now divide the horizontal through A (Fig 8) into an appropriate number of parts and through these points of division, draw verticals from the intrados to the curve DE that limits above the load.

Regard each trapezoid DGG'D' as a rectangle, and calculate its surface by multiplying its horizontal width AA' by the mean vertical dg. Next regarding the centre of gravity of each trapezoid as that of the corresponding rectangle, we shall find the centre of gravity of the trapezoid DD'G'G, for example, to be upon the mean vertical dg. which equally divides the horizontal AA'. Draw through C, the

FIG. 8.



joint CH; the weight DD'G'G will be considered as resting on the joint CH; which is in excess by the small triangle CG'H, an error too small to be regarded in flat arches.

There is, however, given by Dr. Scheffler, a very simple construction for a closer approximation to the truth. Further on will be indicated another method, which gives all desirable accuracy for any form of arch. In fact, considering that in practice arches are neither homogeneous nor symmetrical, perfect accuracy is not necessary, as there should be a margin left to allow for these variations always. In the case of the experiments with the wooden voussoirs, the writer has used a method which leaves nothing to be desired on the score of simplicity and accuracy.

Now if we multiply the surface of each

*Scheffler, p. 222,

trapezoid by the horizontal distance of its centre of gravity from A; the sum of these moments divided by the sum of the trapezoid surfaces (which are also the volumes), will give the horizontal distance from A to the centre of gravity of the whole part considered. This method will thus give us the weights P_1 P_2 - - - (Fig. 3), as well as the horizontal distance of their centres of gravity from the crown.

First Example.—Let us illustrate by an

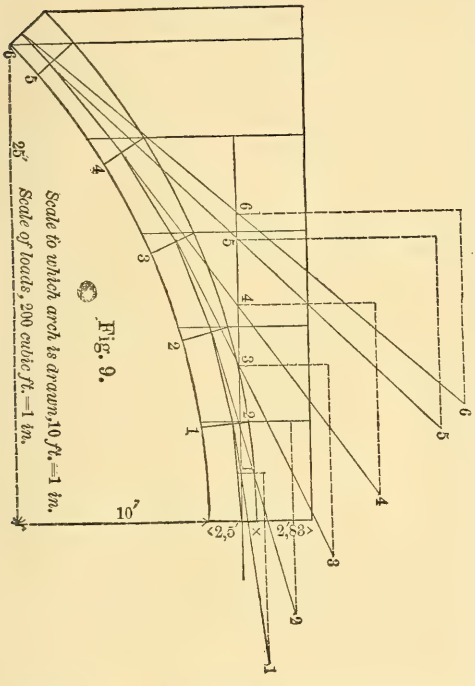


Fig. 9.

example of a railroad bridge (Fig. 9) of 50 ft. span and 10 ft. rise, the arch being a segment of a circle; voussoirs 2.5 deep; the spandrel walls rising 2.83 ft. above the summit of the arch ring. The arch is 7 ft. thick, but we shall consider but a vertical slice of it 1 ft. thick.

In the following table, the first column gives the number of the joint from the crown; the second (w) the width of the horizontal divisions AA', A'A''- - of Fig. 8; the third (v) the corresponding mean heights *dg* - - -; the fourth (s), the product of these dimensions, giving thus the surface of each trapezoid. Column (c) gives the distances of the centre of gravity of each trapezoid from the crown; column (m) the product of (s) and (c). Now we cumulate, giving from the crown in the next two columns these surfaces and products (s + c); column (S) being formed by adding the surface of each trapezoid to the total surface, just found, which precedes it. The last quantity in column (S) should = sum of column (s).

In the same way, column (M) contains the continued sum of column (m), and hence its last number should equal the sum of column (m). Dividing now the numbers in column (M) by the corresponding ones in column (S) we get, column (c), the horizontal distances of the centre of gravity of each weight P_1, P_2 — — corresponding to joists 1, 2 - - - from the crown.

Table 1.

	w	v	s	c	m	S	M	C
1	5	5.4	27.	2.5	67.50	27.	67.50	2.5
2	5	6.1	30.5	7.5	228.75	57.5	296.25	5.1
3	5	7.6	38.	12.5	475.	95.5	771.25	8.1
4	5	9.8	49.	17.5	857.50	144.5	1628.75	11.3
5	5	13.2	66.	22.5	1485.	210.5	3113.75	14.7
6	1.75	14.5	25.4	25.9	657.86	235.9	3771.61	16.
			235.9		3771.61			

The preceding table shows that the *surface* (or *content*, for a slice 1 ft. thick) of the half arch with its load equals 235.9 sq. ft.; its moment as to the crown is 3771.61 and the distance of its centre of gravity from the joint at the crown is 16 ft. Hence (see Fig. 7,) we have to pass a curve of pressures, through the crown joint, $\frac{1}{3}$ of its depth from the summit of the arch and through joint 6 at $\frac{1}{3}$ of its depth above its lowest point, if we decide on account of shocks due to passing loads, imperfection of workmanship, etc., to require that the curve of pressures shall not pass outside of the middle third of the arch ring. By measurement on the drawing (Fig. 9) we find a=25.6—16=9.6, b = 11.2. We have also P=235.9 cubic feet of stone; hence by formula (1)

$$Q = \frac{a\,P}{b} = \frac{235.9 \times 9\,6}{11.2} = 202 \text{ cubic ft. stone}$$

which may be reduced to tons, when desired, by multiplying by the weight in tons of a cubic foot of stone.

If now at the points of intersection of the horizontal through the point of application of Q at the crown, with the verticals passing through the centres of gravity of the surfaces given in column (S), (P_1 P_2- - - of Fig. 3), the points of intersection, of the resultants of Q with these weights P_1, P_2.... with the corresponding joints, will be points in the curve of pressures sought.

For example, to determine where the line of pressures cuts joint 4, lay off the distance in column (C), 11.3 horizontally from the crown, then on a vertical lay off upward from this point the corresponding weight on joint 4, given in column (S) 144.5; drawing a horizontal line, through the last point found=Q, we get the resultant by completing the triangle of forces.

Producing this resultant to intersection with joint 4, will give the centre of pressure on that joint. It will be advisable, in practice, to prick off the centres of gravity, taken from column (C), at one operation and number each one with the number of the corresponding joint to avoid mistake.

On continuing this construction for each joint, we shall find that the line of pressures remains within the inner third of the arch ring.

It may be remarked that the small triangle mentioned is in excess only for the joint in question; thus this error is not carried on. The ordinary method of constructing a line of pressures is to combine any resultant with the next weight following, regarded as concentrated at its centre of gravity.

By this construction any small error in draughting is carried on, whereas, by Dr. Scheffler's method, it is confined only to the joint where it occurs first.

With accurate instruments and care, using a sufficiently large scale, this method of Dr. Scheffler's should answer all the requirements of accuracy, and will generally be found the shortest in the end; whereas, with many joints, it is difficult to locate this curve precisely by the ordinary method.

Second Example.—(Fig. 10.) Suppose a load of two 40-ton engines, one on each

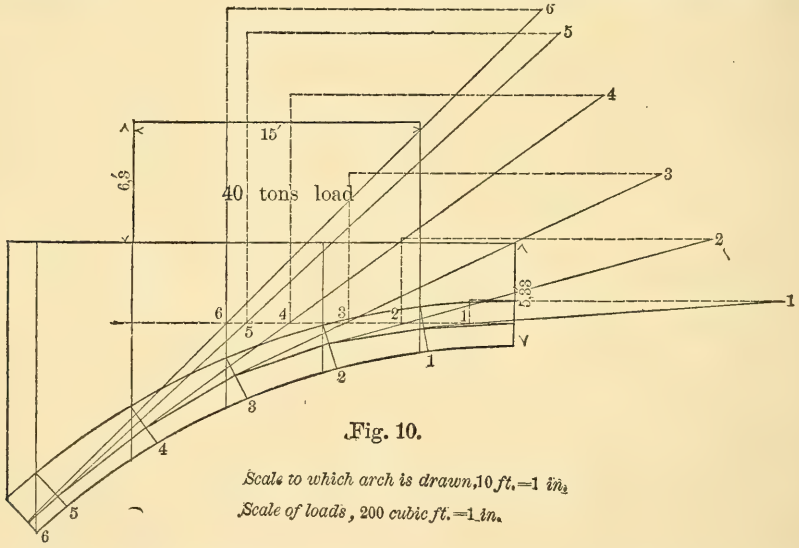


Fig. 10.

side of the crown, over divisions 2, 3, and 4, *i. e.*, 15 ft. along the rails. We shall suppose it to bear only on 6 ft. of the thickness of the viaduct. Calling the weight of a cubic foot of stone=.07 ton and h, the height of the block of stone 15 ft. long by 6 ft. wide that is required to weigh as much as one engine; we have

$$6 \times 15 \times h\ .07 = 40 \quad \therefore h = 6.3.$$

We now form the following table which refers to Fig. 10, which as the arch and load is symmetrical, represents, as before, only one-half the arch.

TABLE 2.

	w	v	s	c	m	S	M	C
1	5	5.4	27	2.5	67	27	67	2.5
2	5	12.4	62	7.5	465	89	532	6.
3	5	14.	70	12.5	869	159	1401	8.8
4	5	16.	80	17.5	1408	239	2809	11.8
5	5	13.2	66	22.5	1485	305	4294	14.1
6	1.75	14.5	25	25 9	658	330	4952	15.
			330		4952			

A line of pressures passing through the middle of the crown, the point on the springing joint, as before, will be found to be contained inside of the limiting curves, and is drawn as in Fig. 10, taking care to lay off the centres of gravity on

the prolongation of Q. We find in this case a=25.6 − 15=10.6, P=330 b=10.7.

$$\therefore Q = \frac{330 \times 10.6}{10.7} = 327 = \frown = 23 \text{ tons.}$$

If it is desired to draw the curve corresponding to the minimum of the thrust in the limits chosen, we resort to equations (2) and (3). As the nearest approach of the last line of pressures drawn to the outside limiting curve, is at joint 2; pass a curve of pressures now through the point of intersection of that outside limiting curve with the second joint and the previous point at the springing joint.

We find P = 330, a = 10.6, e = 9.8 and from table 2, column (S) P_1 = 89; from column (c) and the drawing a_1 = 9.8 − 6 = 3.8.

From (2)

$$\therefore Q = \frac{a P - a_1 P_1}{e} = \frac{3498 - 338}{9.8} = 322$$

From (3)

$$q = h - \frac{a P}{Q} = 11.93 - \frac{3498}{322} = 1.04$$

Laying off this latter distance, from the summit of the arch ring, downwards, we draw the curve as before. It is everywhere within the proper limits. It is not drawn in the figure as it passes very near the first curve.

If we suppose an engine of 13.3 tons weight to rest on division 3 on both sides of the crown, along 5 ft. of the length of the rails, we shall find by forming a table and constructing the line of pressures as before, that it passes slightly below the upper limit at the crown, and is everywhere contained in the middle third of the arch ring.

A curve of pressures for a uniform load of 1.5 tons per foot along the whole length of the bridge, will be found to follow very closely the curve drawn in the first example.

One or two more suppositions of isolated weights, symmetrically placed, were made, but in all cases it was found that a curve of pressures could easily be drawn in the inner third of the arch ring. The thrust is too small to fear crushing, and the directions of the thrust are inclined to the normals of the arch joints at angles much smaller than the angles of friction, hence sliding is not to be feared.

We conclude that thus far the arch has stability.

9.—It occurred to the writer that if the actual line of pressure in an arch composed of incompressible voussoirs, touched the contour curves, as shown in Art. 5, that it should hold very nearly in the case of experiments with light wooden arches, whose weight is not sufficient to produce much compressibility. It will be seen that this law is beautifully illustrated by these simple experiments.

The experiments by the writer were made with great care to endeavor to meet the requirements of an exact science.

Mr. Wm. Bland has published in Weale's series a book entitled, "Experimental Essays on the Principles of Construction in Arches, Piers, Buttresses, etc.," (1867), which contains experiments that we shall quote from. The preference will, however, be given to the writer's experiments, as we do not know *what care* Mr. Bland used in cutting out the voussoirs, in keeping the span invariable, piers vertical, and applying weights, etc.

To avoid mistake, the following nomenclature will be adopted:

Depth of a voussoir is the dimension in the direction of the radius of the intrados ⊥ to the axis of the arch.

Thickness of an arch or pier is the dimension ∥ to the axis of the arch.

Width of a pier is its horizontal dimension ⊥ to the axis of the arch.

Height is measured vertically.

The dimensions will all be given in inches.

A Gothic arch (Fig. 11) of 14 in. span, and 12.12 in. rise, was cut out of a poplar (tulip tree) plank, 3.65 in. thick, consisting of 8 voussoirs, each 3.65 thick, 2 deep, and 4.08 along their centre line from middle to middle of joint; each voussoir weighing .52 lb. Quite a number of voussoirs were cut out of the same layers of fibres and those selected that weighed exactly the same; the voussoir to be tried being hung to one end of a delicate balance beam, with a voussoir of the standard weight at the other end. The two voussoirs at the crown not being cut out of the same layers of fibres as the others, were shaved off about the middle of the extrados (not touching the joints) so as to weigh exactly 1 voussoir of the standard weight and their centres of gravity were found experimentally, and found to be at exactly similar points in both voussoirs, so that the entire arch was symmetrical as to the crown.

The centres of gravity of the other

voussoirs are taken on the arc of a circle passing through the middle of the joints and for any voussoir equidistant from the joints bounding that voussoir. For voussoirs whose sides are little inclined, this is sufficiently near the truth, and by dividing the arch ring into a sufficient number of artificial voussoirs, the result may be made as accurate as we please. Still as no wood is homogeneous the results can only be regarded as approximate as compared with the hypothetical homogeneous arch; still sufficiently near to establish the laws heretofore demonstrated.

When this arch was set up, the joints apparently fitted perfectly, and on placing a drawing-board by the side of the arch and tracing off its contour curves, it was found to be a perfect Gothic whose arcs, composing the contour curves were correct arcs of circles described from the springing points opposite.

A number of rectangular wooden bricks of exactly 1 voussoir in weight, of various sizes, were also cut out, as well as half bricks, quarter bricks, etc., and some solid rectangular piers of various dimensions.

A voussoir is taken as the unit of weight.

In experiments where weights were placed upon the top of the arch, an assistant added brick after brick, carefully balancing the load at the top on either side by the fingers, until the arch reached its *balancing point; i. e.*, the point where it stood with the weight, but fell with a slight jarring.

The two bottom voussoirs were, when necessary, kept from sliding by two fastening tacks being driven into the board on which the arch rested, pressing against the arch .03 above the springing line, or so little that it may be disregarded. The board was carefully levelled at every experiment by a spirit level, and the span kept invariably at 14 in.

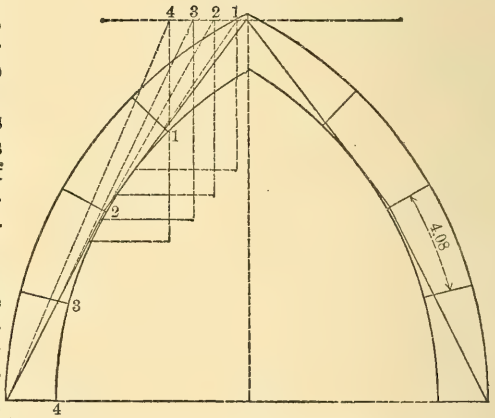
There was little or no vibration in the room.

First Experiment.—With 8.2 voussoirs on the summit of the arch it stood, though fell with 8.3 voussoirs on the summit; rotating on joints 2 on intradosal edge and at the summit; the arch being forced out at the haunches and falling at the crown. (See Fig. 11.)

The following table gives in its first column the number of joint from the crown; column *s*, the *elementary weights* (4.1 voussoir being the weight on the summit that goes to each abutment, the weight of each voussoir being taken as unity); column *m* gives the horizontal distance from the crown to the centre of gravity of each voussoir with its load, if any, which, in this case, is also the *moment* in reference to the vertical through the crown of each voussoir. Columns S, M, and C have been before explained.

	s	m	S	M	C
	4 1	0.00	4.1	0.00	0 08
1	1.	1 70	5.1	1.70	.33
2	1.	4.68	6.1	6 38	1 04
3	1.	6.79	7.1	13.17	1 85
4	1.	7.88	8.1	21.05	2.6
	8.1	21.05			

FIG 11.



Try a line of pressures, passing 0.1 from the upper edge of crown joint (*i. e.* at the *summit*) and 0.1 from the extrados edge of the joint at the springing. From the drawing and table we find $a = 6.3$, $b = 14.27$, from which equation (1) gives us

$$Q = \frac{8.1 \times 6.3}{14.27} = 3.57$$

The line of pressures drawn with this value of Q and passing through the points indicated cuts joint 2 at 0.1 from its lower edge. From joint 0 to joint 2 the line of pressures corresponds to the minimum of the thrust; from joint 2 to joint 4, to the maximum, for if the point of application at the crown is lowered to the point at joint 2, being moved from the edge, the same amount, the centre of pressure at joint 4 is moved to the left, outside its limiting position, which, as just seen, is in this arch 0.1 from the contour curves, for in *no other position* of the line of pressures than that first found, will it cut the

joints of rupture 0,2 and 4, at the same distance from the contour curves, which, as the material of the voussoirs is nearly homogeneous, it is reasonable to conclude, should be the case. As there can be no greater nor less thrust, we conclude that the arch is on the limit of stability, as the experiment indicates.

0.1 is $\frac{1}{20}$ of the depth of joint.

Sliding would have occurred on joint 4, as the resultant on that joint made an angle of 24 deg. with the normal, but for the tacks before mentioned.

The diagrams for this and all the following experiments were drawn to a scale of one-third the natural size, except in the case of some of the pier experiments.

Second Experiment.—With the two voussoirs at the crown in one solid piece, the arch could not give by rotation, as the lower edge of crown joint could not open. With a sufficient pressure on the crown, there was sliding along joints 4, the coefficient of friction being small for these wooden blocks.

We evidently have here a sufficient reason for making the keystone in one solid piece.

Third Experiment.—On placing a knife edge against a notch .03 deep, cut into the bottom voussoir, 0.4 above the springing line, on each side, the arch balanced with 11.1 voussoirs on the summit. The line of pressures must now pass through the knife edges, and it will be found on constructing a diagram that it will pass about 0.1 from edges at joints 0 and 2, as before.

Fourth Experiment.—(Fig. 12.) The same arch stood, being very nearly on the balancing point, on *solid* piers 10. high, 1.9 wide, and 3.65 thick, each pier weighing 2.3 voussoirs, the intrados at the springing being at the inner edge of pier. The piers were made vertical by a spirit level, and their tops were upon the same level, in every experiment given.

In the following table the pier is included opposite joint 5 of the first column.

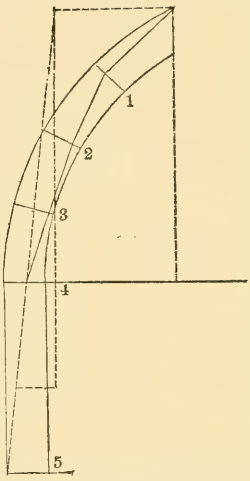
	S	c	m	S	M	C
1	1	1.7	1.70	1	1.70	1.7
2	1	4.68	4.68	2	6.38	3.19
3	1	6.79	6.79	3	13.17	4.39
4	1	7.88	7.88	4	21.05	5.26
5	2.3	7.95	18.28	6.3	39.33	6.24
	6.3		39.33			

To pass a curve of pressures 0.1 from the edges of joints 0 and 2, which will be found to correspond to the minimum of the thrust, we find from the above table and the drawing

$$Q = \frac{3 \times 2.2}{10.5} = .63$$

from which the curve of pressures in Fig. 12 is drawn, as before. This curve approaches the intrados nearest at joint 3, cuts joint 4 at .58 from the inner edge, and the base of the pier .2 from the outer edge or about $\frac{1}{10}$ the width of pier.

Fig. 12.



Fifth Experiment.—With piers 40.47 in. high, 3.65 wide, and 1.9 thick, weighing 10.1 voussoirs each, with the intrados of arch at springing on a line with inner edge of pier, the same arch balanced. The pier was built of a solid block 22 in. high, and 5 bricks placed on top, one above the other to make up the 40.47 in height.

A line of pressures drawn .1 from summit and .1 from intrados at joint 3, passes .5 from outer edge of pier, or about $\frac{1}{7}$ width of pier.

It will be found on constructing the diagrams for Mr. Bland's experiments, where the piers were built up of bricks, that in the case of low piers as in Figs. 51, 52, 53, 54, 55, 45 (*Exp.* No. 5), and 46 (*Exp.* 8), the line of pressures passes very near the outer edge of the base of the pier; but as the piers were increased in height, this line approaches more and more the centre of the base, being in the case of a pier 6 × 6 base and 72 in. high, nearer the centre of the base, than its outer edge.

It is probable that this is caused by the outer edge of every brick, when the line of pressures passes on that side of the centre, *compressing* a small quantity, as a great many irregular surfaces of contact must cause a greater compression than if the pier was solid. Again, the additional pressure on the lower bricks of a high pier is an evident cause for greater compression than with a low pier. A high

pier of many bricks appears to *bend* in consequence of that compression of its many edges. It may be inferred from these facts that the greater the thrust in an arch the farther the line of pressures retreats within an arch; which we shall find to be so in the sequel.

Sixth Experiment.—The pier of *Exp.* 4 (Fig. 12) was moved outward (*from* the axis of the arch) so that when its inner edge was .1 from the springing, it stood with no weight on the summit; when it was .4 from edge, it stood with .5 vs., fell with .6 vs.; .5 from edge, balanced with .75 .vs.; .6 from edge balanced with .75 vs.; .7 from edge balanced with .37 vs.; 1.0 from edge balanced with .12 vs.

From which we infer that the centre of pressure at the springing joint is .5+5.1 (to allow for compression)=.65 from inner edge of joint for a weight of .75 vs. on the summit or apex of the arch. On constructing the table and diagram for this weight it will be found that theoretically the centre of pressure at the springing joint is .63 from the inner edge, which differing only .02 from the distance found by experiment must be regarded as a beautiful experimental illustration of the theory.

Seventh Experiment.—The same arch stood easily with .75 vs. on the summit, on solid piers, 22. high, 3.65 wide, and 1.9 thick each weighing 5.1 vs.; the arch fell with the addition of .12 vs. more.

On constructing this figure it will be found that the line of pressures, assumed 0.1 from edges of joints 0 and 3 as before, passes .63 from inner edge of springing joint (as was stated above) and cuts the base of pier .39 from its outer edge or about $\frac{1}{3}$ the width of pier.

Eighth Experiment.—On moving this pier back as in the 6th *Exp.*:

0.47	the	arch	balanced	with	1.12 vs.
0.53	"	"	"	"	1.25 "
.59	"	"	"	"	1 25 "
.63	"	"	"	"	1.25 "
.7	"	"	"	"	1.12 "
1.	"	"	"	"	1.00 "

Taking .58 as the probable distance and adding .1, we get .68 as the probable distance back from the springing to the centre of pressure of joint 4. On constructing the line of pressures for a weight of 1.25 at the apex, passing 0.1 from the edge of joints 0 and 3 as before, it will be found that the centre of pressure on joint 4 is .7 from the edge, which is again a most striking coincidence, as it differs but .02 from the joint found experimentally. These experiments were made with great care, keeping the span exactly 14 inches, piers vertical, etc., etc.

Compare similar experiments by Mr. Bland (Figs. 56 and 57), where the same law is established approximately.

It is evident from an inspection of the arches in churches (for examples see drawings in the latter part of Mr. Bland's treatise) that constructors were well aware that a higher pier might be used when its inner edge was moved back a certain distance from the springing, which is equivalent to what we have established above.

Ninth Experiment.—With the pier used in *Exp.* 4, and the same arch, excepting that the two voussoirs at the crown were in one piece, the arch and pier just balanced as in *Exp.* 4. In fact, the arch and pier can easily rotate on the third joint and the outer edge of pier.

Tenth Experiment.—The same arch with piers 1.98 wide, 7.5 high and thickness of arch, each weighing 2 vs., stood easily when a cylindrical pin .03 in diameter was placed at the lower edge of crown joint. This joint bore at no other point, hence the line of pressures presses through the pin. Assuming it to pass .1 from the edge of joint 3, the construction will show that it cuts the springing joint .6 from inner edge and the base of pier .15 from its outer edge.

The *experiments* that we have just considered, very clearly indicate the fallacy of that theory which supposes that if a line of pressures passes outside the inner third of the arch ring, *that it must fall.* On the contrary, in every case of stability of the arches previously given, it is *impossible* to draw a line of pressures everywhere contained within the inner third of the arch ring. In fact, if such were attempted it would be found in every case that such a line of pressures would pass *outside* the base of the piers, or of the arch if used alone.

It is hardly probable, in most actual arches, that this line of pressures ever keeps within the inner third.

Theoretically, for the voussoir arch, there is no foundation for such a theory, and we confess to astonishment when we read in Prof. Rankine's "Engineering," Art. 280, "It is true that arches have stood, and still stand in which the centres of resistance of joints fall beyond the middle third of the

depth of the arch ring; but the stability of such arches is either now precarious, or must have been precarious while the mortar was fresh."

As we have just asserted, in our experiments "the centres of resistance of joints" invariably fall outside the middle third, for certain joints, and if an experiment were made with a 50ft. arch it is not probable that at the joints of rupture, the centres of resistance would be found as far back from the edge as $\frac{1}{3}$ or even $\frac{1}{5}$ the depth of joint.

It may be well enough on account of the shocks to which bridges are subject to design an arch in which a line of pressures may be drawn within the inner third, but it is by no means necessarily true that the line of pressures can never pass this limit without the stability of the bridge being rendered precarious, though it would seem that this error has likewise been received in France (see "Traité de la Stabilité," etc., p. 220) by eminent mathematicians.

This subject will be referred to again in Art. 10. In all the experiments with arches the same voussoirs were used in the same positions each experiment.

Every experiment is given that was made, so that the reader may judge for himself how far the theory of Dr. Sheffler is established. No force diagram was drawn until after, and in some cases long after, the experiment was made; and no second trial was resorted to in any case.

All other writers but Dr. Scheffler, so far as the writer knows, have left the true line of pressures, in many cases at least, perfectly *indeterminate*, and it is Dr. Scheffler who has raised that indetermination by means of the principle of the least resistance and given us a theory which is upheld by experiment. Some authors actually assume the line of pressures to pass through the middle of the joint at the crown and springing.

It is evident how much more incorrect this is even than the fallacy of the "midole third."

[To be Continued.]

IRRIGATION WORKS IN THE BATTICALOA DISTRICT OF CEYLON.

By Captain W. PHILLPOTTS, R.E.

From the Papers of the Royal Engineers.

To assist in developing the resources of a semi-civilized country is one of the most interesting of the very varied duties we can be called on to perform in our distant colonial possessions. The means of doing so varies with the nature of the country; but in the tropics, I know of none which goes more directly to this object than giving to a capricious and fitful stream a certain supply of water, and thereby rendering the land through which it flows capable of profitable cultivation. This is particularly the case in the East, where rice is the staple production, for there is no other species of cultivation which requires such a regular and constant supply of water to bring it to perfection.

The necessity of irrigation works in the East has long been recognized as paramount. No matter what the vices of ancient governments have been, they must at least have the credit of having constructed some of the most gigantic and successful hydraulic works in the world. We read of these as occurring in many parts of India, and from personal observation I can testify to the magnitude, durability, and skill evinced in similar constructions by the ancient inhabitants of Ceylon; and I much doubt if any other countries of similar size present specimens of finer engineering works than are there shown by the dams, canals, and tanks, or, as they would be more appropriately termed, lakes, with which it abounds. These ancient works are, however, mostly partially in ruins, after centuries of neglect and decay, but even in their present state they testify to the extraordinary boldness of conception which initiated them, as well as to the enterprising skill displayed in their execution.

It would require a history of Ceylon to trace the causes of their destruction, suffice it to say, that constant wars and bad government so reduced the population, that cultivation was partially abandoned, then disease followed, and carried off its thousands; whole districts were deserted by their inhabitants; the works themselves fell out of repair; nature, left to itself, rapidly changed fertile fields to jungles infested with wild beasts, so that now the finest hunting grounds which the

sportsman visits are in the midst of the most interesting remains of the former grandeur of the country.

The Batticaloa District, which is on the eastern side of the island, is particularly adapted for the growth of rice, so much so that it has long been called the granary of Ceylon. Up to the date of Sir Henry Ward's government, 1856, no permanent works had, however, been undertaken for its irrigation. Here were no vast ruins as in other places, which was to be accounted for by its remoteness from the ancient seat of government, and its comparative natural facilities for rice cultivation. It was, however, acknowledged that certain works, comparatively small, would be of immense service to the district; and the governor, having convinced himself of the necessity of these by personal inspection, in company with Major Gossett, the surveyor-general, at once authorized their execution. I do not for a moment mean to say that these works bear any comparison with those executed under the ancient kings of Ceylon, but they were the most extensive, and the only systematic ones, which our government had undertaken, so that I must confess to have been gratified to find myself placed in charge of them, and I venture to hope that a description of them will not be uninteresting.

Our predecessors in the rule of Ceylon —the Dutch—with their usual sagacity and skill where any hydraulic works were necessary, had devoted the most unceasing care to the irrigation of this district, the fruits of which were shown by the quantities of grain it produced. Strange to say, however, their works were not of a permanent character, and their dams were merely mounds of earth, without any masonry. This can only be accounted for by the absence of skilled artificers, and the abundant population of common field laborers; the former could only have been imported at great cost, while the latter were always available, and could be employed without any expense whatever. This was owing to the system of Rajahkaria, or forced labor, which gave the chief officer of the district power to call out as many men as he wanted to repair or construct any works necessary for irrigation. These men got no pay, each landowner having to supply them according to the quantity of land he possessed, and as the works were entirely for their benefit, they were glad enough to have the labor combined for the common weal. The system followed was this, after the great periodical rains and floods, the dams of the tanks were repaired, and as much water stored in them as circumstances permitted. In the dry season the dams were cut, and the water allowed to run off to the river, which conveyed it to the fields. The next floods, while they refilled the tanks, breached the dams, which had again to be repaired, and thus it went on from year to year. It is superfluous to point out the inconveniences of such a system as this, the waste of labor must have been enormous, and it was never possible to keep the tanks full, on account of the difficulty of repairing the dams before a quantity of water had run out, added to which, the floods were so uncertain that the repairs had to be made two or three times for one crop.

The English, on succeeding the Dutch, pursued much the same system until the abolition of forced labor in 1836; this put it out of the power of government to work men without pay. The legislature would not incur the heavy annual outlay which the alteration of the law called forth, and no steps being taken to collect the necessary labor, the tanks became useless, the supply of water most uncertain, and in bad seasons the cultivators were reduced to the greatest privations. Although when Sir H. Ward visited the district in 1857, the tanks had long ceased to be of any use, yet most distinct traces of their existence remained; these in a few years had become covered with jungle, and formed the abodes of the various wild animals with which this part of Ceylon abounds. But even had the works been utterly obliterated, those were living who had seen them in action, had preserved a grateful recollection of their effects, and had long cherished the hope of their restoration, now speedily to be realized. The scheme, therefore, which the government had to decide on was eminently a safe one, inasmuch as the good effects of the Dutch works were universally acknowledged; that it would prove a remunerative one was also probable, for by extending the works a large amount of crown land would become capable of cultivation, and be eagerly purchased by the natives, while by increasing the capa-

bilities of existing fields, the value of the tithe due as a tax to government would also be enhanced.

The lands to be irrigated were all dependent on one river, the Pattepola Aar, for water; this river takes its rise in the south-east portion of the interior table land of Ceylon, and like all other rivers there, has a very precipitous course until it reaches the low flat country along the sea coast, which it does about 40 miles from its mouth. Here the banks become low, and the course tortuous, but its general direction is north-west, until it expands into a large lake running north and south, at the north end of which it joins the sea. The land on its banks is rich alluvial soil, the very best for the growth of rice, and the deposits left by the floods have the most fertilizing effect. Before entering the lake just alluded to, it forms a delta, intersected by numerous watercourses, all supplied by the same river. The river has the peculiarity which is, I believe, common to all the deltaic rivers, its proper bed is elevated above the surrounding country, so that its course may be said to extend along a ridge; this is caused by the constant deposits left by the floods year after year, and it shows itself at once by the inclination which the stream has to burst away from its channels. This peculiarity has its advantages, as it greatly facilitates bringing water to the land, for it is obvious that as long as water could be kept in the main channel, it can always be drawn off to land below that level. The object of the works was, therefore, to give the means of sending a supply of water into the river whenever it ran dry, and confining it to the main channel.

During the rainy season, from November to February, the river was generally full; and it was also during this season liable to the most violent and sudden floods, which inundated the country for miles. In March and April the supply of water became uncertain; in May the river generally ran dry, and remained so, with the exception of an occasional fresh until November. A small, but certain, supply of water during these dry months was all that was necessary to make the land the finest rice country in Ceylon. To meet this supply it was determined to restore two of the largest old reservoirs which the Dutch had used, called the Tanks of Erecamam, and Ambarree. It was thought at the time that if these two sites were made the most of by efficient permanent works, that sufficient water would be secured, and subsequent experience proved this correct.

I shall now proceed to a description of these tanks, premising that the word "Tank," as used in the East, means a large reservoir some hundreds of acres in extent. The usual way to form a reservoir, is to build a dam across a valley, and thus intercept the water flowing from the surrounding hills, a stream generally being taken advantage of to secure a constant supply. The height of the dam is determined by the quantity of water required, care being taken to provide spill-waters to prevent the water rising above its proper level, and thus breaching the bund.

Erecamam Villoo, as it was called, was an exception to this rule, being peculiarly situated; it was not a valley, nor did any river flow through it. It was a large hollow plain or basin, 1,000 acres in extent, on the river's bank. Low, undulating wooded hills surrounded the plain on all sides, with the exception of about three-fourths of a mile, where it had the river for its boundary. When the river rose over its banks, it filled the plain, which again became dry on the flood subsiding; it was, therefore, necessary to adopt some means which would let the flood in, and when in to keep it there until required. In the course of time the river had worn a narrow channel into the plain, and through this a large quantity of water found its way, still more, however, ran over the low flat land adjoining the river. It will be remembered that the Dutch had used this tank, and when I first visited it the line of their bund was clearly seen. It was breached in numerous places, and was merely a succession of isolated mounds of earth covered with trees. A new bund was built along the line of the old one, and its height was fixed at 24 feet above the river's bed. The level of the tank was fixed at 9 feet below the crest of the dam, which being level terminated at either end, when the line of the crest came to within 9 feet of the natural ground; these ends were protected by circular retaining walls, and the ground beyond levelled for about 40 yards, so as to allow the floods to flow

freely round the dam. They, in fact, became spill-waters over the natural ground. The floods usually rose two or three feet above this level, but as that was not always to be relied on, the channel before referred to as leading from the river to the tank was kept open, and provided with flood-gates to be closed as soon as the tank was full. The height of the dam varied from 9 to 24 feet, and its length was half-a-mile, its slopes were 2 to 1 on each side, and its width at top 6 feet. It was composed of a stiff clayey soil, got close at hand, and carefully watered and rammed in horizontal layers one foot high; when finished the sides were planted with grass, which grew very rapidly and formed a capital protection for it. The excavation and carriage of the earth to form the dam cost from 3½d. to 6d. per yard cube. A sluice in brick masonry, with two water-ways 6′×4′ was built in the bund. This was provided with doors sliding in grooves so as to command the supply of water. The channel communicating with the river varied from 60 to 70 feet in width, and 8 to 12 feet deep. In designing the flood-gates for this channel, the object was to keep the waterway as wide as possible, and the scarcity of skilled labor necessitated their being as simple as possible. I first thought of making them a series of doors hung on pivots above the centre of gravity, so as to be self-acting, but the quantity of logs brought down by the floods rendered this inexpedient. I therefore adopted the plan of making the gates to consist of single horizontal planks, supported at either end by a pier of masonry, and intermediately supported by wooden posts so arranged as to make the plank a manageable weight for two men. The total width of the gate was 63 feet, and this was divided into 3 spans 17 feet wide by two 6-feet brick piers. Each of the bays was divided into three by two upright posts strutted to the apron, and the planks rested against them, so that they were supported every five feet. The planks were fitted with iron hooks for raising and lowering them. The apron was kept on the same level throughout, which was six feet below the level of the tank; this was 30 feet wide, and, of course, extended completely across the channel; the junction with the banks being protected by retaining walls carried well into the firm soil. This was very important, inasmuch as the whole work would be completely inundated in floods, and have 3 or 4 feet of water over its top rushing into the tank at the rate of 6 or 7 miles an hour. The apron consisted of three brick walls, 6 feet thick, and 6 feet apart, varying in height from 3 to 4 feet. Transverse walls 3 feet thick were built to connect them, and the intervening spaces filled with well-rammed clay. The foundation of this work was not difficult, inasmuch as decomposed granite rock was found in the bed of the channel, of sufficient hardness to give a firm base, and yet yielding to a well-pointed pick. In one part sound rock cropped out at an angle of 18°, this was prepared for receiving the first course of masonry by throwing in brick concrete. The apron was paved partly with brick on edge and partly with stone, the latter being used when the water fell over the dam. This work was about 400 yards from the end of the dam, and the intervening ground being flat, and rather above the level of the tank, was left as it was to admit of the floods flowing over it as freely as possible. At the other end of the dam was another channel, but much smaller, and on a higher level; a small work was built here on the same principle as the larger one, with the addition of raising the piers and abutments to support a bridge. Before deciding on these works, I had an opportunity of observing the river in flood, as I lived on the spot during a rainy season, before doing anything more than commencing the bund. A continuous residence there of 3½ years confirmed the view I first formed. Knowing the river so well was of the utmost advantage to me, as the description of its state during the rains, which I had received from natives, gave a very faint idea of the violence and extent of the floods to which it was subject. I was completely astonished on witnessing the first flood. For some four months before no rain had fallen, the river was dry, the wells dry, and all vegetation completely shrivelled up; for about a month even the dew, that beautiful source of moisture in a tropical climate, was wanting. The rain set in about the middle of November, and in its first burst it was an incessant down pour for seven days; about the fifth day the river began to rise above its banks, and in the next 36 hours it rose with marvellous rapidity, completely inundating the country for miles around, and surrounding my camp, which I had pitched

on a flat hill, with water to within 6 feet of its summit; all communication was stopped except by canoes, but it was only possible to work these down the stream on account of the strength of the current. On the 8th day the rain ceased, and the river fell as rapidly as it rose, and in a few days the face of the country was completely changed.

The foundations of the sluice and upper gates were also brought down to the rock, which at these places rose to near the surface. You will find drawings of all these works, showing their construction, in detail.

AMBARREE VILLOO.

I shall not go so minutely into this, its situation being similar to Erecamam. Everything connected with it was designed on the same principles, but on a smaller scale. You will find plans of all the works connected with it on the table.

It was very interesting to watch the effects of the various works the first flood after their completion. The river rose with its usual violence, the waters rushed into the tank through the flood-gates, but before the tank filled these were completely flooded, and almost unapproachable, the bund was surrounded with water, which rushed into the tank round the retaining walls at either end. Soon after the flood was at its height, the water on either side of the dam seemed to be at rest for a few minutes, then it rushed out by the same way as it came in, until it had subsided to the level of the ground at either end, and the top of the flood-gates; these were at once closed, the operation being performed easily by four men, notwithstanding the rush of water through them. The tank was now full, the water extending some distance into the jungle which bounded the plain of Erecamam, necessitated the abandonment of a village on one side of it.

On one side of the plain of Ambarree was a very sacred small stone idol in the figure of a man; it had been there for ages, and the natives used to come for miles to make offerings to it. During the progress of the works, and by questioning me on the subject, they found that the water line of the tank would just reach the god's chin. Here was a dilemma, either the god must be moved from the position he had occupied for centuries, or he must be immersed in water half the year. Recourse was had to the oracle of the temple, who decided that he was to remain in his watery position.

The area of the plain of Erecamam was over 900 acres, but the surface covered with water was between 1,300 and 1,400 acres.

In Ambarree the area of the plain was 600 acres, and of water when the tank was full, between 800 and 900 acres. The calculated contents of the two tanks, when full, are nineteen million cubic yards of water in Erecamam, seven millions in Ambarree.

A watercourse was cut from the sluice of each tank to the river, so that this quantity was under perfect command to supply the river when it ran dry, during the cultivation season.

I shall not attempt to describe the delight of the people at seeing such a quantity of water stored up for their cultivation; they felt that they were now certain of tilling their land profitably, and they gave substantial proofs of this by their eagerness to buy up the crown lands, a statement of the proceeds of which I shall presently give.

VEREADDY CATTOO OR DAM.

The only formidable escape of water from the main channel of the river was down the branch called the Vereaddy Aar, running into Akrapattoo, the slope of this branch was so rapid that it took off a very large quantity of water, much more than the land through which it flowed required, while for six or eight months in the year it completely drained the Sengepaddy Aar, or upper stream, to the great injury of the Carawagoo lands. The former land had too much water, the latter not enough, to equalize the supply; it was, therefore, determined to construct a regulating dam at its head. This was not intended to prevent the heavy floods going down the Vereaddy river, for that would have been impossible, but it was simply to prevent such portions of the summer freshes as were not wanted in Akrapattoo, and thus to force them into the Sengepaddy river.

The design for this work required careful consideration, on account of the quantities of sand brought down by the floods. A simple wall with sluices and aprons across the river's head might, for a few years, have answered the purpose, but the sluices would constantly have been choked with sand, and the dam itself would have presented a most formidable obstacle to the

winter floods, which it was useless to attempt to stop; I therefore determined on a work similar to the flood-gates at Erecamam, that is a dam composed of masonry piers, and wooden posts supporting horizontal planks, to be removed singly. During the season of floods, the dam is kept entirely open by taking out the planks, it then presents to the stream no more obstacle than a bridge would do; the floods are thus freely allowed to flow off, and there is no accumulation of sand above the dam. You will find a detailed plan of this work on the table. The only thing in which it differs essentially from the work at Erecamam is the foundations; here the bed of the river was loose sand from 9 to 10 feet deep, when clay was reached. In the foundation I adopted the plan almost universally pursued in Southern India, viz.:—continuous wells sunk 9 to 10 feet in the river's bed. Two rows of wells were sunk across the river to correspond with the width of the apron, intermediate wells for the piers being also sunk; these wells were then filled up with a mixture of clay and broken brick, and the apron, 3 feet thick, was built upon them in brick masonry. This system of foundations is particularly well adapted to rivers of this kind, and is almost universal in the Madras provinces; it was the first time, however, it had been adopted in Ceylon, and I was obliged to get the workmen from India. There is a class of men who do nothing else, and are in consequence called well-sinkers. The first two or three feet can be sunk by any intelligent workman, but after that the men work under water by diving, and it is only those who are accustomed to this sort of work who can stand it, and even to them the work is so severe that they have constantly to be relieved. Strange to say, what they suffer most from is cold, and that with a blazing tropical sun over them sufficient to raise the temperature to 110° or 120°. They work naked, and when they come out of the water the evaporation from their skin is very rapid, this makes them intensely cold; they adopt a novel means of warming themselves; as soon as they come out of the water, they cover themselves with hot sand, and there lay until their turn comes round for work. As a rule, three men work at each well, one of whom is always resting in this way. Physically, they are a fine race of men, and are all but amphibious.

Vereaddy Dam has completely answered the purpose for which it was designed; it affords the means of throwing five feet of water into the Sengepaddy river, a quantity amply sufficient for all the land through which it flows, and by simply withdrawing the planks the quantity of water going into the Vereaddy Aar can be regulated with the greatest nicety. The first closing of this work was not less interesting than that at Erecamam; the position of the two rivers was reversed, the branch which had before carried off all the water was now dry, it being forced into the Sengepaddy channel, and the delight and surprise of the natives at seeing the hitherto unruly river brought under control was most gratifying. It was curious to see how the fish were deceived by it, numbers were caught just above the dam, while others, in their attempts to pursue their accustomed haunts, got jammed in between the planks, or found themselves landed on the nearly dry apron below.

The chief difficulty experienced in carrying out these works was the scarcity of skilled labor; this had to be brought from the south of India at great cost. The unhealthy nature of the climate was also a great drawback, and it was quite melancholy to see how the workmen suffered. I believe this will always be the case in carrying on works in a wild part of a tropical country; I had sad experience of it here among my men, although the works were not more than ten or fifteen miles from thickly populated and healthy villages. The materials used were bricks, stone, and lime, the former were taken from some ruined temples in the vicinity, but the lime had to be transported partly in boats and partly on bullocks' backs a distance of 50 miles. It was burnt from coral, and very excellent mortar it makes; to render it more hydraulic, I mixed brickdust with it, generally in the proportions of 2 of brickdust, 1 sand, 2 slaked lime.

In considering artificial irrigation for rice, the question will naturally arise, how much water is necessary, say for an acre. This must vary in different countries, besides which, some kinds of rice require much more water than others. In Ceylon, even the statements given me on this subject by intelligent farmers differed greatly, the most reliable information I could procure, however, made it appear that an acre of rice required a supply of 4,000 cubic

yards of water, extended over a period of 90 days. General Cotton, the great irrigation engineer of Madras, gives the quantity at 5,000 cubic yards, while the late Colonel Baird Smith, equally celebrated for his works in Bengal, states that a cubic foot of water per second is sufficient for 40 acres. It is so impossible to reconcile these statements, that the discrepancy must arise from different systems of cultivation. In Ceylon a constant supply was not required.

In conclusion, a brief statement of the financial results of the works will be interesting. They cost £16,600. For the 10 years previous to 1861, the goverment tithe on the lands watered by the works averaged £1,805 per annum; in the year 1861 it was £2,055, being an increase of £1,250 per year, which the works secured to the revenue of the province. This £2,055 represents the annual tax on 14,000 acres of ground which were in cultivation before the works were commenced, but which were effected by the works, inasmuch as they afforded a certain supply of water, instead of the hitherto precarious one. Besides this, some 6,000 acres of crown land were rendered capable of profitable cultivation; a considerable portion of this had been sold in 1861, and realized £9,046, and as soon as it came into cultivation it would yield an additional revenue to government of from two to three shillings per acre. The financial results, therefore, have been very satisfactory, and the social benefits conferred on the natives by encouraging them to adopt settled and permanent cultivation as a means of subsistence are incalculable.

Since writing this paper I hear that recent experience shows the result of these works in a still more favorable light. A statement, proving their utility and success, was made by the Surveyor-General on the 20th December, 1862, when the vote for the up-keep of the works was brought before the Legislative Council of Ceylon; and as it points out most clearly the benefits—both financial and social—resulting from the works, I cannot do better than conclude this paper with an extract from the Surveyor-General's own remarks on the occasion.

He said: "I am glad that my honorable friend has brought forward this subject, because I believe an inpression exists abroad to some extent that the returns from these works of irrigation have been quite inadequate to the outlay. I cannot think so myself. Both the works of Erecamam and Orrobokke are, in my opinion, decidedly successful. I cannot say the same of Devittore; still nothing as yet has been brought to account there.

"The returns show that £10,000 have been received from land sales and fees at Erecamam, against £18,000, the cost of the works and up-keep to date. Besides which there ought to be considered the increase to the annual revenue from the augmented taxation. Formerly 1s. was levied per acre over the 10,000 acres of old paddy land in the irrigation districts. It was proposed that this should be raised 2s. 6d. on account of the works, and that this rate should be exacted from the new lands. This should give an increase of more than £1,000 a year. I do not know for certain whether the rate has been raised to this figure, but I believe it has been. Then in 1858, 1860, and 1861, the country was visited with severe drought, and the crops of those years were entirely due to the successful operation of the irrigation works. When in Batticaloa, I was told that the value of the crop might be estimated at £20,000; so that these works have been the means of saving £60,000 to the native inhabitants of that district. It is not difficult to find out the value of a crop in money, but who is to estimate the amount of privation and even mortality that would have ensued had these works not been constructed."

Russia possesses a remarkable system of river, canal, and lake communication, the importance of which has not been destroyed by the railways. The configuration of the ground, mostly flat, is very favorable to navigable water-routes, which attain in the country a total length of 34,770 kilometres, or 1 kilometre per 143.7 square kilometres of territory, and for every 1,831 of the inhabitants. To appreciate these numerical results, however, regard must be had to the average length of season in which navigation is practicable; this is in Russia, only 239 days in the year. In the north the fluviatile communications are possible only 6½ months; in the south (on an average) 9 months.

LOCOMOTIVES FOR ASCENDING STEEP INCLINES WITH SHARP CURVES.

By Lieut. J. G. HALL, R.E.

Papers of the Royal Engineers.

Not many years ago it was supposed that the adhesion between the driving wheels of an engine and the rails was such as not to allow of railways being worked with steeper gradients than 1 in 120 or 1 in 100, but practical experience has lately shown the fallacy of those ideas. Numerous samples may be cited of railways, both in Great Britain and abroad, where the gradients range from about 1 in 60 to 1 in 30, but I shall confine myself to a few of the most important ones, with a short description of how each is worked. Beginning first with those at home, we have the St. Helen's Railway. With regard to this line, the *Times* says:—"This line running through a hilly, mineral district, has a most remarkable combination of sharp curves and steep gradients. In a length of about 30 miles it has a constant succession of curves, varying from 500 down to 170 feet radius, and it has gradients from 1 in 85 to 1 in 35. This line has been usually worked by short engines on *six wheels*, four of them being coupled as drivers, and connected to separate tenders for the supply of fuel and water; the length of the wheel base of the engine was 12 feet. Even this comparatively short length of engine was disadvantageous on curves, involving much impedimental friction; and a still greater disadvantage was that tender engines are only adapted to run safely with the tender behind, and in the working and shunting, the loss of time, labor, and the expense was considerable. In lieu of those six-wheeled engines, a locomotive of quite a novel construction has been lately introduced. This engine is capable of running either end foremost, and of passing with a free, rolling movement round curves of two chains. The engine is on eight wheels, covering a base of 22 feet, and the length of the solid frame is 32 feet in length. The four central wheels have their axles, which are rigidly parallel to each other, passing through before and behind the fire-box, the axles being about 8 feet apart. It is quite obvious that so long an engine could scarcely pass round curves at all, even at any cost of friction, with the ordinary construction of wheels and axles. This difficulty is got over in the following way:—The tires of the four centre wheels already mentioned are applied on hoop springs of elastic steel placed between the wheel and tire. On these springs the tires can slip or revolve without sliding on the rails, and thus the revolutions of the tires are adjusted to the varying lengths of the rails on curves by self-action. The sliding of the wheels on the tire is not found in any way to impede the tractive power of the engine, but, on the contrary, rather to increase it. The extreme pair of wheels at each end have the same arrangement with regard to the tires, but the axles have very long bearings, and the boxes in which they run, instead of being parallel to the axles, are formed in curved lines struck from central points, and are permitted to move in this curvature through the horn plates and axle guides beneath the spring shoes. The result of this is, that the wheels and flanges are free to follow the curve of the rails, with this very important advantage in point of safety, that the extreme axles on curves always point truly to the centre of the curve, and, consequently are square to the rails even though the curve may be in the form of the letter S, requiring the axles to radiate in opposite directions."

Among other steep inclines in this country may be mentioned the Lickey incline on the Birmingham and Gloucester Railway. It has a ruling gradient of 1 in 37, and is worked by two locomotives coupled together, one of them weighing 35, and the other 32 tons, and they take up an average goods train, which is about 300 tons load, at a rate of 6½ miles per hour. The Dainton Incline, on the South Devon, is also very steep, being 1 in 45; and there is also an incline near Oldham, on the Manchester and Oldham Railway, with a gradient of 1 in 27. Most of these

inclines were formerly worked by stationary engines and rope traction, but this method of working inclines has fallen into disuse from two primary causes:—1st, that locomotives can do the work as well, and are more convenient. 2nd, Where the curves are numerous and sharp, it becomes almost impracticable to use a traction rope. Another reason might also be urged, that there is always a risk of the rope giving way and thereby causing very serious accidents.

Abroad steep inclines are becoming very common, and it is abroad that some of the most remarkable are to be found. The three following are the most worthy of notice, viz.:—the Semmering incline on the Vienna and Trieste railway, the Giovi incline on the Turin and Genoa Railway and the Bhore Ghaut incline on the Great Indian Peninsular Railway. The Semmering incline was opened in 1854; its entire length is 19.47 miles, and the gradients range from 1 in 40 to 150. The curves range from 9½ chains radius to 14 chains radius. It is at present worked by an engine designed by M. Engerth, the Austrian Government Locomotive Superintendent. The following is a brief description of the type of engine used:—It consists of two parts, the forepart carrying the boiler, fire-box, &c., is supported on three pair of coupled wheels, and the hind part is a peculiar description of "bogie" which carries the driver's platform and fuel, and is supported on two pair of wheels. The water is carried in tanks at each side of the boiler, so that the whole weight of boiler, tank, &c., is available for adhesion. The total weight of the engine, when filled, is 55¼ tons, and is distributed in the following manner: 13½ tons on the leading wheels, 12¼ on the centre, and 13 tons on the driving wheels, and 8¼ tons on each pair of trailing wheels. These two pair of trailing wheels were afterwards made into assistant drivers by means of axles with toothed wheels keyed on them. The total heating surface is 1,660 square feet, of which 75 square feet is fire-box surface. The number of tubes are 189 of 2 inches diameter, and 15 feet 7 inches in length. The grate area is 12·6 square feet, or 1⅓ of the heating surface. The diameter of the cylinders, which are outside ones, is 18·7 inches, and the stroke 25 inches. The wheels are all 3 feet 7¾ inches in diameter. These engines are 380 horse power, and can draw a load of 160 tons (engine included) up an incline of 1 in 40 and at a speed of about 10 miles per hour. About .73 cubic feet of water per horse power is evaporated per hour.

"The Giovi incline on the Turin and Genoa Railway commences about 7¾ miles from Genoa, at a point 295 feet above the level of the Mediterranean. It ascends there for about 6 miles to an elevation of 1,1°4 feet, being an average gradient of 1 in 36." The steepest gradient is 1 in 29, and the smallest 1 in 50. These gradients have curves of a minimum radius of 20 chains.

The locomotive power employed for ascending the incline, is obtained by using two engines of the same size, constructed by Messrs. Robert Stephenson and Co., of Newcastle, each carrying its own coke and water, and resting on *four coupled* wheels, with outside cylinders. The wheels are 3 feet 6 inches in diameter, and the cylinders 14 inches, the length of stroke being 22 inches. These two locomotives are bolted together, so that the fire-boxes are opposite each other, and they are manned by one driver and a stoker. When filled they weigh altogether 55¼ tons; the wheels nearest the fire-box carrying about 14 *tons* each, and the other 10 *tons*. In fine weather the locomotives carry up 100 tons, and in the worst, never less than 70 tons at a speed of 15 miles per hour.

The Bhore Ghaut Incline, by which Bombay is put in immediate connection with the Deccan, is 15⅛ miles long, rises 1,831 feet with an average gradient of 1 in 48, the steepest being 1 in 37. It was opened in March, 1863, after having been in hand for 7¼ years.

The engines with which this incline is worked are *fourteen* in number, worked in pairs by coupling them back to back. They carry their own water tanks and are without tenders. Each engine has two pair of coupled wheels, 4 feet in diameter. The cylinders are 15 inches in diameter, and length of stroke 22 inches. The total weight of each engine when in working condition is 34½ tons.

Abroad great attention has been given to the construction of locomotives for ascending steep inclines with sharp curves, and, as a class, they are quite different from those used in this country.

On the *Northern Railway* of France, for instance, some of the heavy gradient locomotives have as many as *six* pair of wheels, coupled in two sets of *three*, with two pair of cylinders, and the fore and hind axle boxes have 1¼ inch play transversely to admit of their running round sharp curves of 600 feet radius. Their average weight in working condition is 57 tons, the whole being available for adhesion.

Mr. Clark (M. Inst. C.E.) in his paper on the locomotives in the International Exhibition of 1862, with regard to this type of engine, after referring to their top-heaviness and the overcrowded state of the tubes, says:—"The best thing about these engines is the uniform distribution of the weight, giving great tractive power without distressing the road on the straight portion; but the wheel base is impracticably long, and must greatly strain the engine and road, as well as add to the resistance on sharp curves. The proportion of the tractive power, taking the effective mean pressure in the cylinders at 80 per cent. of the boiler pressure for low speeds, is about one-sixth of the weight for adhesion, which is a fair proportion, and utilizes the immense weight of the engine."

There is another type of locomotive which is coming rather extensively into use on the continent (though it has not met with much encouragement in this country), and that is what is known by the name of the "bogie" type. They are very much to be recommended for sharp curves and steep gradients, and where the length of gradient is such as to warrant the expense of their construction. They are often as much as 60 tons in weight and generally have all their wheels coupled to the drivers.

I cannot well dismiss this part of my subject without saying a few words about a kind of engine which, no doubt, will quite revolutionize railway engineering. The invention, which is the subject of a patent taken out by Mr. Fell, Engineer, Sparkbridge, Lancashire, consists in obtaining additional adhesion other than that obtained by the weight of the locomotive itself. It is carried out in the following way:—Horizontal wheels in pairs are so arranged as to work on either side of a central rail by means of cylinders, and a steady and constant pressure is obtained between the wheels and rails by means of springs, though, of course, the pressure may also be produced by means of a steam cylinder, or even by water pressure. There is also an arrangement by which the pressure of the springs can be increased or dimished at pleasure.

In order to avoid friction in a vertical direction between the wheel and central rail, resulting from the movement of the engine on the springs which support it, vertical play is allowed. These wheels can also be used as brakes. The proposed immediate application of the invention, is to work locomotives and carriages on the steep inclines over the Alpine Pass at Mont Cenis and thus connect the French and Italian railway system ten years sooner than it could be accomplished by the completion of the great tunnel through the Alps, commenced some years ago by the French and Italian governments. For this purpose it is proposed to construct a railway on a portion of the existing public road between St. Michel in Savoy, and Susa, in Piedmont. The distance is about 48 miles, and the width sufficient to accommodate both the local and the railway traffic. Some of the gradients are upwards of 1 in 12, and the curves are generally very sharp. A locomotive on this principle has lately been tried on the Cromford and High Peak Railway. It drew a load of 20 tons, which is equivalent to 100 passengers and carriages, up an incline of 1 in 12, and round a curve of 2 chains, at an average rate of from 7½ to 12 miles per hour. The adhesive weight of the engine tried was 16 tons, and with the aid of the horizontal wheels it was increased to 32 tons; it was also found that the "grip" of the horizontal wheels was so firm, that with the addition of the brakes attached to the several carriages, the train was stopped on the incline.

Without stopping to discuss the merits of the various methods hitherto adopted for working steep inclines with sharp curves, I shall proceed to lay before you two plans I have to propose, and I ought to mention here that both of the projects under consideration were, as far as the general principles are concerned, the subject of a paper that I forwarded to the Institute of Civil Engineers, December, 1862, but as it only contained plans not executed or attempted, it therefore did not

come within the scope of its regulations, and, consequently, was not read at the meetings of the Institute.

A locomotive, having the propelling power within itself, advances by means of the adhesion between the touching points of the surface of the driving wheels and of the rails on which it is moving. This adhesion is only another term for the friction caused by gravity, or the weight of the locomotive pressing against the rails, by which, when the driving wheels are put in motion by the engine, an abutment, as it were, is presented to their motion *in situ*, necessarily causing them to advance, as the only motion they are susceptible of under the circumstances. But for the frictional resistance, produced by the weight of the locomotive between the particles of iron at the touching surfaces of the rails and wheels, the latter would merely revolve on their axes *in situ*, without any advancing motion.

Frictional resistance is experienced by all rolling bodies, and is obstructive of their motion, causing and representing a certain loss or expenditure of power in overcoming it. But in relation to the special action or function of the driving wheels of a locomotive, this resistance is beneficial, and necessary to the efficient application of the power in propelling the locomotive, and enabling it to draw whatever is attached to it.

The most favorable position for realizing the full effect of the surface adhesion between the rails and the driving wheels, is when the rails are perfectly horizontal, and the weight of the locomotive pressing in the line of gravity at right angles to the rails.

THE CAUSES OF THE FORMATION OF BARS AT THE MOUTHS OF RIVERS, AS SHOWN IN AN EXAMINATION OF THE CONNECTICUT RIVER.

By Gen. THEODORE G. ELLIS, C. E.

Transactions of the American Society of Civil Engineers.

The Connecticut River rises in the extreme northern part of New Hampshire, almost upon the border of Canada, and flows southward between the States of New Hampshire and Vermont, crossing the states of Massachusetts and Connecticut, and enters Long Island Sound.

In the States of New Hampshire and Vermont, its watershed is narrow and precipitous, and its tributaries are mostly small, partaking of the character of mountain torrents. In Massachusetts the drainage area is more extended, and streams of some size enter from the east and west. In Connecticut but one stream of any size enters the river. Below Hartford the tributaries are small, and, except in heavy rains, furnish but little water. All of the streams flowing into the Connecticut bring down more or less detritus in freshets.

From its source to the Massachusetts State line, the banks of the Connecticut are generally of a permanent character. Through the State of Massachusetts the river passes mostly through an alluvial formation, though in some places the bed is hard and permanent. From the town of Northampton to Hartford, and southward as far as Rocky Hill, the river flows through alluvial meadows overflowed in high freshets. In many places through this region the banks are washed away by the river. From about two miles above Hartford to nine miles below, the banks are generally a clay-loam upon the outside of the curves or bends, and upon the opposite side are low sand beaches, deposited by the river in freshets. The banks upon the outside of the bends are wearing away rapidly, generally caving off by being undermined, but in some cases the clay slides out from the bottom and rises up in the river, the top sinking down for 20 or 30 feet back to a level of 8 or 10 feet lower than before. The part that slides out soon washes away, and the operation is repeated. This part of the river furnishes a great amount of silt, and is continually changing its bed.

From Rocky Hill to the Narrows, below Middletown, the banks are more permanent and less subject to wash. At two or three

places, however, they are wearing away by the action of the water. Through the Narrows, for about a mile, the banks are high and rocky, and the channel deep and narrow. From this point to the mouth of the river the banks suffer but little abrasion from the action of the water, and are generally hilly, sloping downward to the water, and in many places rocky. The bed of the river, in the upper part, where it does not reach the rock, is coarse gravel; through the alluvial region it is generally a hard, fine sand, which becomes mixed with more or less mud in the lower part of the river near its mouth.

The Connecticut River is subject to freshets of considerable height, which mostly occur in the spring, when the river is swollen by the melting snow, although freshets have occurred in every month of the year, except June, July and September. The highest known freshet was in May, 1854, when the water rose to a height of 29 feet and 10 inches above low-water at Hartford.

The great height of the freshets at Hartford is due to the contraction of the waterway at the Narrows, just below Middletown. The river at this place is only 650 feet wide at the ordinary water-line, with steep and rocky banks rising to a great height on either side, so that the width probably does not exceed 800 feet at the highest water level. Through this gorge all the water must pass, which in freshets overflows the banks above and spreads out in some places nearly two miles in width over the meadows through which the river runs. The effect of this contraction is seen in the small fall in the surface of the water in floods between Hartford and Middletown. Middletown is about one-third of the distance from Hartford to the mouth of the river, and the average fall of water between these points in high freshets is only about one-sixth of the total fall. The distance from Hartford to Saybrook light is 49 miles.

The volume of water discharged by the Connecticut River is about 7.500 cubic feet per second at low stages of the water, and rises as high as 160.000 cubic feet per second in high freshets. The average discharge during the year 1871 was 19.388 cubic feet per second. The average velocity of the water varies from one to four miles per hour, according to the stage of the river.

During the spring freshets, the upper waters and tributaries of the Connecticut bring down large quantities of silt, which is deposited along its course, and upon Saybrook bar at its mouth. At high stages a large amount is deposited upon the meadows above Middletown, where the river spreads out to a great width, and the current is checked. Bars of sand are formed in the eddies, which wash away as the river falls. The finer particles held in suspension are carried forward by the current and deposited lower down or carried out over the bar at the mouth of the river. After the water has fallen, so as to be confined within its banks, through the alluvial region between Northampton and Rocky Hill, these banks are washed and carried off; furnishing a great amount of material to be deposited below.

At ordinary summer level, the tides affect the river to a point about seven miles above Hartford, the rise and fall at Hartford being about 10 inches; at Saybrook the mean rise and fall of the tides is $3\frac{1}{2}$ feet. As the water rises the tides disappear. At 5 feet there is no tide at Hartford. In extremely low tides and a south wind, there is sometimes a reverse current as high up as Middletown. The slope of the river from Hartford to the sound, at ordinary summer level and mean tides, is about 2 feet. Above Hartford the slope becomes steeper and more irregular.

The foregoing details of the character of the river, although briefly stated, will give a sufficient idea of the nature and amount of detritus that may be expected to flow out at the mouth and be deposited in the sound.

In order to know what becomes of the material brought down by the river, it becomes necessary to investigate the currents and other natural causes affecting it after it leaves the river and enters the sound. The nature of the tides and tidal currents in Long Island Sound may be stated briefly as follows: The tidal wave from the ocean approaches the entrance to the sound from the southeast and flows into it, past Fisher's and Plum Islands, mostly through the middle part, called the Race. Another tidal wave enters the west end of the sound through New York Bay. These tides meet at some place between Sand's Point and Throg's Neck, according to the state of the tides. The wave passing up the sound from the Race is partly a wave of trans-

mission, with a progressive velocity depending upon the mean depth of the channel, and partly an actual flowing in and out of water through the Race. The crest of the wave of transmission moves from the Race to Sand's Point, a distance of 95 miles, in two hours. As the tide rises, the water pours through the Race at a maximum rate of about 5 miles an hour. This current opposite the mouth of the Connecticut River is about 2½ miles an hour. As the crest of the wave passes, the currents set back again in the opposite direction with about the same velocities.

As the tide rises in the sound, the currents set in towards the shore; and as it lowers they set outward from the shore, taking a direction slightly diagonal to the general direction of the central current.

At dead low-water the current from the river spreads out over the whole bar. The greater volume, however, follows the central or southeast channel. There are two other channels over the bar, one to the eastward, near the shore, and another to the southwest, with nearly as deep water as the central channel. When the rising tide commences to flow in from the southeast, it first dams back the river water and forms a distinct line of ripples along the outer edge of the bar. As the tide continues to rise, the stronger flow sets this ripple farther and farther on to the bar; turning back the current from the river, and throwing it farther to the westward, until what still flows out passes through the southwest channel.

From half-tide upward, a strong current sets in along the shore towards Griswold's Point, and flows across the mouth of the river, and partly into it, setting the fresh water back and raising the height of the water in the river. Just before the highest water, the current turns and sets strongly to the eastward along the shore, west from the light-house, impinging strongly upon the current flowing out from the river, and forming a well-defined ripple, extending southwest from the light. The great volume of water coming from the river, that has flowed into it on the rising tide, maintains its current southward until the tide has somewhat fallen, when the great volume of water sweeping down the sound overcomes the obstacle and pushes the river current over to the eastward, into and beyond the main central channel. This action of the littoral currents is evidently what forms the two side channels to the east and southwest.

Along the southwest edge of the bar, the outer bank is for a long distance very steep. This is probably caused by the strong wash of the ebb tide flowing along the shore from the westward, and striking upon the outer edge of the shoal.

A very complete survey of the mouth of the Connecticut River has been recently made by the writer, with a view to permanently improving the channel, which shows with great exactness the present form and state of the bar. By comparison of this with the maps of earlier surveys, we are enabled to determine the changes that have been going on, and study the causes which produce them. It will be unnecessary to go into all the details of changes which have occurred from time to time, as it would consume too much space, and prove uninteresting without having copies of the several maps to refer to. The principal changes only, and those having reference to the formation of the bar, will be noticed.

A comparison of the present survey with the United States Coast Survey Chart of 1853, and with a survey made in 1836, by Col. Julius W. Adams, will show the principal changes that have occurred during the past thirty-six years at and near the mouth of the river. Prior to September, 1815, as shown on Col. Adams's map, Griswold's Point extended much farther to the west than at present; reaching some 400 feet beyond what is now known as Poverty Island. To the north, between Griswold's Point and the foot of the island, was the channel of Blackball River. In continuation of Griswold's Point, with a channel of about 200 feet between, was an island of above 2,300 feet long and 700 feet broad, of an oval form, extending out nearly to Griswold's north pier. The Blackhall River had two outlets, one on each side of the easterly end of the island.

In the gale which occurred in September, 1815, the whole of this island and the western portion of Griswold's Point, back to a long distance beyond its present limits were washed away. The ordinary action of the waves and currents again commenced to re-form the parts carried off, and, at the time of Col. Adams's survey, a point called Poverty Island beach had run out about 1,500 feet from the southwest corner of the large island now called Poverty

Island, upon the ground formerly occupied by the island washed away; and Griswold's Point had extended out to within 1,000 feet of its present limits. The mouth of Blackhall River was then just west of this point.

At the time of the coast survey, in 1850, Poverty Island beach had extended out still farther, and more to the north, to a length of 2,200 feet, and deeper water existed around it than before, Griswold's Point had also lengthened out about 600 feet. Poverty Island beach extended out some 200 feet farther, and was afterwards gradually washed away; being worn down by the action of the waves or river floods, and perhaps both; leaving at the present time but a small island of about 600 feet long, now known as Poverty Island Point. Griswold's Point has to the present time farther lengthened out about 500 feet.

The general outlines of the bar, as shown by the three surveys, are nearly the same. Although the outlines as shown by Col. Adams are not so extensive as those of the Coast Survey chart and the present survey, yet the two latter do not essentially differ, as to the extent of the bar, at the 18 feet contour line. There have been other minor changes, but none that affect the general character or the causes of formation of the bar.

It will be seen from the foregoing account of the principal changes at the mouth of the river, that great changes are constantly going on upon the eastern side, in the continual formation and occasional washing away of extensive spits and islands, while the western side remains always the same. The cause of this is to be found in the action of the waves during the continuance of the prevailing winds and storms. These are from the southeast, and the waves, acting diagonally along the shore, drive the material of which the beach is formed to the westward, until it meets the descending current of the river, which limits its farther motion in that direction. This wave action is constantly going on, and all the material carried forward eventually finds its way out upon the bar, either by being gradually transferred by the river current or by being washed out at once in a large quantity, as was the case when the island and point were carried off by the gale of September, 1815.

There is another important action of the waves besides that which transmits material along the shore; that is its action upon the outer edge of the bar. It is well known to all who have had occasion to examine the action of the sea upon an inclined shore, that it never carries off or swallows up anything. Everything is cast ashore or pushed out upon the beach, and the largest and heaviest things are thrown the farthest out and highest up upon the beach. This is caused by the progressive movement of the waves as they roll in upon the shore, and the same action occurs upon the outer edge of the bar to a depth equal to that of the same wave action upon the shore. The material of the bar is being constantly forced backward, up to a point where the river current is sufficiently strong to prevent its farther motion, and neutralize the action of the waves.

This wave action upon the bottom has been advanced as the sole cause of bars; the only conditions necessary being:

1st. The presence of sand or shingle, or other easily moved material.

2d. Water of a depth so limited that the waves, during storms, may act on the bottom.

3d. Such an exposure as shall allow of waves being generated of sufficient size to operate on the submerged material.

Where these conditions exist at the mouth of a river running into the sea or large lake of fresh water, a bar would undoubtedly exist, even though no sediment was discharged by the stream; but there are other causes which form bars, where one of the conditions above might not exist, viz., the limited depth of water before the commencement of the formation of the bar. In this case the action of the waves along the shore carrying sand or shingle into the mouth of the river, as it does in the Connecticut, would soon raise the height of the bottom so that it could be operated upon by the waves and raised into a bar, or the material might be supplied by suspended silt, or sand carried by the current along the bottom, which would be deposited in the dead water at the mouth of the river, and be formed into a bar in the same manner.

When a river brings down silt suspended in the water, a favorite theory has been to suppose that the bar is formed by the deposit of this silt when the fresh water meets the salt. The silt is supposed to remain suspended until the current is checked

by the fresh water expanding out over the surface of the underlying salt water, when it is deposited and is carried back by the under current of salt water as the tide enters the mouth of the river, thus forming the bar. The principal objection to this theory is, that bars are formed where streams enter fresh water lakes, and the supposed conditions do not exist.

Another theory of the formation of bars at the mouths of rivers, which has been advanced by the highest authority upon river hydraulics, is, that the sand and mud which is drifted along the bottom by the river current, passes into the sea until it meets the dead angle formed by the rising of the fresh river water over the salt water, when it is deposited and forms the bar. It is not explained what would be the effect of a river flowing into a fresh water lake, where all the water was of the same density; but for a stream flowing into salt water, this theory is amply sufficient to account for the formation of a bar. In the bar upon which observations were made to determine the cause of its formation by experiment, this was found to be the case.

I am led, however, to believe, from an examination of the Connecticut, and comparison with published records of other rivers and estuaries, that no single one of the theories named will account for the formation of all bars. In many cases a variety of causes are in operation to produce a bar and modify its form, either one of which might have produced it acting alone, but which all conduce to give it its existing form. In other cases fewer causes operate to create the bar, and may be different in different bars. In the Connecticut we have many forces in operation to give the bar its present form.

Its material appears to be largely composed of detritus brough down by the river in times of freshets, although some portion of it is washed from along the shore to the eastward by the action of the waves, and some may be swept across the mouth of the river by the littoral tidal currents of the sound. The silt brought down by the river during freshets, and the coarser material that is swept along the bottom are carried out and deposited upon the bar, where their character is modified by the action of the waves and by the tidal currents flowing in and out over the bar when the water in the river falls to its usual level, so that only the coarser part remains, the finer particles of silt being swept away. That part of the bar which remains nearly permanent, or subject to gradual and progressive changes, is mainly composed of coarse sand, much more difficult to move than the ordinary deposits which are formed in the lower portion of the river bed. The form of the outer edge of the bar is probably modified by the strong littoral tidal currents which flow back and forth in this part of the sound. The effect of the current from the westward, however, is more marked than that from the eastward, as it seems to limit the extension of the bar in a southwesterly direction by eroding its outer edge.

From the foregoing, and what has been previously said regarding the wave action along the beach to the eastward, and the action of the tidal currents in forming the side channels over the crest of the bar, it will be seen that we have the following general causes operating to create the bar at Saybrook and modify its form:

1. The suspended silt brought down by the river in freshets, which deposits upon the bar by the decrease of velocity in the stream.

2. The sand and coarse material which is swept along the bottom, and rolls out upon the bar until it meets the water of the sound.

3. The wave action which carries material along the beach towards Griswold's Point, to be in time carried out upon the bar by the river current.

4. The wave action affecting the outer slope of the bar to modify its form and drive back the material.

5. The littoral tidal currents flowing up and down the sound, and the current flowing in and out of the mouth of the river, which erode certain parts of the bar, and probably deposit material upon other parts, and otherwise shift and assort the material brought drown by the river, washing away the lighter particles, and thereby modify the general form and character of the bar.

The decrease of velocity in the river water named above may be either on account of the rising and spreading of the fresh water over the substratum of salt water, or over the crest of the bar itself; although the latter may be considered as a consequence of the bar rather than as an original cause of its formation.

At Saybrook there seems to be two

classes of causes operating conjointly to maintain the bar. One class furnishes the material, viz., the suspended silt, the sand washed along the bottom, and the material carried along the beach to the mouth of the river by the wave action. The other class retains the materials upon the bar, viz., the rising of the fresh water over the salt, and forming a dead angle, the spreading out of the water over the bar already formed, and consequent checking of the velocity, and the wave action upon the outer slope of the bar.

It is not presumed that all of the above causes operate upon every bar; one of each class, acting together, would undoubtedly create and maintain a bar. They are named to show that all bars may not be produced by the same causes, nor be accounted for by the same general simple theory. Examples of the formation of bars from different causes may be seen in the deposits at the mouths of the river Wear, at Sunderland, England, and of the Dornoch Firth, in the north of Scotland; which are almost entirely due to the wave action of the sea; and in the vast accumulations at the mouth of the Mississippi and Danube, which are wholly formed of detritus brought down by those rivers. The bar at the mouth of the Wear is shown by dredgings to be formed of the same material as the adjacent beaches, viz., sharp, gritty sand, brickbats, chalk, flint, pebbles, and marly rock; materials which could not by any possibility have come from the river. The bar at the mouth of the Dornoch Firth is fourteen miles to seaward of where the fresh water joins the salt, and is composed of a sharp sand, while the small rivers which discharge into the firth bring down very little silt, and that is of an alluvial character. The material of which the bar is formed is evidently washed from along the shore by the progressive action of the waves from the north sea, with its inner slope modified by the currents from the firth, and its outer slope by the wave actiod throwing it back. The bar at the mouth of the Mississippi is, without doubt, wholly formed of the sand and mud carried by the current along the bottom, and deposited in the dead angle between the fresh and salt water, as has been described; and the same may be said of the Danube, except that the immense amount of suspended silt brought down by that river into the tideless Black Sea has, perhaps, a more important part in the formation of the bar than the suspended material of the Mississippi, which is carried farther out to sea.

I think the wave action upon the outer slope of bars at the outlets of rivers has a greater effect in modifying their form than is generally supposed. An examination of the outer slope of such bars shows an inclination about that assumed by a beach of the same materials to a certain depth, which is generally that to which the water is affected by waves. The slope then makes an angle, and becomes much flatter. This flatter portion is probably below the influence of the waves, and the sediment lies where it is deposited. This is seen in the form of the Saybrook bar, where there is a flat portion at about 12 feet in depth; in the Mississippi bar, where it is about 100 feet in depth, and also in the sections of other bars of which surveys have been made. The steeper part of the slope just over the crest is evidently not formed in the same manner as the steep lower side of river bars, lying above where they are affected by the tide, in which the slope is formed by the particles of sand which have been rolled to the crest by the current, and drop down the lower side by their gravity. The slope is too flat for this idea to be entertained.

The littoral currents of the ocean also tend to modify the form of bars, as is seen in the Connecticut by the erosion of the southwestern edge of the bar, and in the form of the channels across the crest. These currents also carry off the finer portions of the sediment and deposit it in other localities.

About a mile to the southwest of the extreme point of Saybrook bar, a long sand shoal commences, and stretches westward for about six miles, averaging at the 18 feet depth about one-quarter of a mile in width. The material which forms this shoal probably comes from Saybrook bar, and is carried along by the incoming tidal current, while the outgoing tide keeps the channel open between it and the shore. The exact method of formation of this shoal, however, has not been investigated, and it may be due to other causes than those named. Its form and character are taken from the coast survey charts, and it cannot be seen to have any effect upon the form of the bar proper, although it is probably derived from it. On account of its distance, and the deep water between, it

cannot properly be considered a part of the bar.

It is proposed during the coming season to commence some permanent works for improving the channel over the Saybrook bar. Some new ideas are believed to be advanced in the improvements contemplated, by taking advantage of the littoral currents to maintain the channel; but no description of them will be attempted at the present time. It is thought they will be successful, and, if so, they will be described at some future time.

RUSSIA, HER INDUSTRIES, COMMERCE, AND MEANS OF COMMUNICATION.

By LEONE LEVI, Esq.

Journal of the "Society of Arts."

The holding of another session of the International Statistical Congress called me to St. Petersburg this year. We met on former occasions at Brussels, Paris, London, Vienna, Berlin, Florence, and the Hague, and everywhere we were received by the Government of the country with great honor and hearty hospitality. The Russian government offered every facility for our journey, and I accepted the invitation to the Congress, and attended it as one of the deputies for the Statistical Society. As for the choice of route, it practically rested between a sea route by Sweden, and a land route, either by Kœnigsberg and Eydkuhnen, or by Berlin and Warsaw. I decided to go by the land route *via* Warsaw, and to return by Stockholm, Copenhagen and Hamburg, and on Saturday, August 10, I, accompanied by my good wife and two dear friends, went from London, *via* Harwich, to Rotterdam—by an excellent boat, it may be, but with more on board than she was fit to carry with comfort; from Rotterdam to Utrecht; thence to Hanover and Berlin, and from Berlin by Bromberg to Warsaw. Utrecht is a quiet and handsome town, Dutch in character, and beautifully clean. At Hanover I saw the effects of the change of dynasty; and Berlin, since I last visited it, has become an imperial city, richer than ever in museums and monuments, but too many, alas! devoted to military heroes.

Warsaw, the ancient capital of Poland, I was glad to see, though I could not help feeling regret for the down-trodden city, where Kosciusko fought with so much valor for the liberty of his country. Yes, there she was, on the banks of the Vistula, with her palaces turned into barracks, and her monuments diverted from their intended purposes. But there is life in Warsaw, and there is a good deal of trade and industry. In 1869 the exports and imports of Poland amounted to about £17,000,000, the exports consisting principally of rye, wheat, timber, flax, and bristles. The railway has rendered Warsaw the best point of transit between Austria, Prussia, and Russia. From Warsaw our route was due north, almost a straight line to St. Petersburg, about seven hundred miles in length, and thus we had ample opportunities of seeing a considerable portion of Russian territory. But how different from the usual English scenery! For miles and miles scarcely anything interesting attracted our notice. Before us was an interminable plain, not a hill to be seen, not even a valley. Surely nature is capricious in her gifts. Go to Italy, Switzerland, or Scotland, and you find the towering mountain, the precipitous rock, the fearful torrent, land and water defying by their grandeur and sublimity the ability of the greatest artist to reproduce by the pencil or the chisel. Go to Russia, and travelling seems monotonous to a degree; but do not think that Russia is so uniformly flat. The Ural mountains, which form a natural frontier between European and Asiatic Russia, the Caucacus mountains also separating Europe from Asia, in the the south, the Carpathian mountains in Bessarabia, and the hills of Finland, are all of considerable height.

What we noted on the road was the poor aspect of the agriculture, the sandy soil, the stunted trees, the rarity of farmhouses, and the almost total absence of sheep. How barren everything looked! For agricultural purposes Russia has been divided into seven distinct regions. The northern region, from the Gulf of Bothnia, to the

northern part of the Oural mountains, including Finland, Archangel, Wologda, and Olonetz, have very little of tillage land. The region of the Alaounes heights, or the plateau which separates the basins of the Dnieper and the Volga, is mostly forest land. The tillage land is not very fruitful, the meadow land scanty. The Baltic region, including Livonia, Courland, and Esthonia, is not very fertile, though somewhat better cultivated. The lower region, including some of the provinces through which we passed, has a very poor soil, and is principally forest land. The Carpathian region, embracing Urkaine and Little Russia, is the most fertile part of the empire. There is the region of the Steppes, including Bessarabia, Kherson, and Astrakhan—a land without trees, seldom watered by refreshing rain, yet eminent as pasture land. The central region, comprising Kostroma, Moscow, Nijni, and Wladimir, is rich in cereals. And the Oural region, including all the eastern part of European Russia, has a soil generally fertile. To show the difference between other regions and the one over which we passed, while Tula, Kursk, Vorones, Tambov, and Kief, have from 60 to 70 per cent. of tillage land, the provinces on our way have at most 40 to 50 per cent. If, then, we did not see any rich soil, or any well cultivated land, they do nevertheless exist in Russia. Does not Russia supply us yearly with large quantities of grain? In 1861 only 12 per cent. of our imports of grain came from Russia; in 1871, the proportion was 35 per cent. In 1861 the total imports were 37,646,000 cwt., and from Russia 4,540,000 cwt.; in 1871 the total imports were 44,362,000, and from Russia, 15,670,000 cwt. The meadow lands of Russia are principally in Finland and Archangel in the north, and in the Don Cossacks and Caucasian provinces in the south. In these provinces Russia has a large stock of some 25,000,000 head of cattle, and 45,000,000 sheep. As for horses, the great centre of horse-breeding seems to be at the very border of the Oural mountains. Russia is stated to have 18,500,000 horses, when the United Kingdom has only 2,600,000. The great difficulties which hitherto have hindered the agricultural progress of Russia have been serf labor, want of capital, want of intelligence, bad roads, and great distances. Now serfdom, in principle at least, is abolished, and the railways are providing new means of access to far distant provinces. May we not hope that with these, capital and intelligence may also find their way thither, and that together they may tend toward the development of resources far exceeding our present expectation? It has been calculated that, while Belgium and the Netherlands produce 14 hectolitres of corn to every hectare of arable land, and England 13 hectolitres, Russia produces only 6 hectolitres. What if, by the means indicated, the productiveness of land could be doubled? With her immense area Russia might replenish the granaries of Europe with the greatest ease.

But fancy travelling in the interior of Russia in sumptuous railway carriages—how different as compared with the time when Richard Chancellor accidentally got into the Bay of San Nicholas, on the White Sea, landed near Archangel, then only a castle, and travelled on sledges to the Czar at Moscow! The first-class railway carriage in Russia is really luxurious. It is a saloon, with all the necessaries, and some of the elegancies, of such an apartment. It is furnished with looking-glasses, heated by porcelain stoves, and lit by lamps and candles. Along the sides soft divans are ranged, which, by a simple process, are turned into beds. But they are in no hurry in Russia; while here we travel at the rate of 30 to 40 miles an hour, there the ordinary rate is from 15 to 20 miles an hour. From St. Petersburg to Moscow, 430 miles, we employed 17 hours. The fares in the Russian railways are lower, of course, than in this country. The average fares on the five principal lines are as follows:

	Copecs per Verst.			Pence per Eng. mile.		
	1st Class	2d Class	3d Class	1st Class	2d Class	3d Class
St. Petersburg to Moscow	3.10	2.11	0.77	1.40	0.95	0.34
St. Petersburg to Warsaw	2.96	2.20	0.92	1.33	1.00	0·46
Moscow to Nijni.	4.9	2.27	1.13	1.33	1.00	0.51
Riga to Nunaburg	4.06	2.59	1.73	1.96	1.22	0.77
Odessa	2.95	2.21	1.06	1.33	1.00	0.46

The division of classes in the Russian railways is much more distinct than in the English railways. The third-class passengers are mostly peasants, clad in the most miserable manner, and many with visages almost forbidding. The stations are commodious, and the buffets well-furnished, nor are the prices so extravagantly high as is often represented. On the whole, Rus-

sia is in a fair way of being largely intersected by railways. On the 1st of September, 1871, there were in Russia 11,138 versts, equal to 7,351 miles of railway, and the capital employed in them was 918,000,000 roubles, equal to £122,000,000. In the United Kingdom the capital so invested in 1870 was £530,000,000. The number of passengers carried in Russia was only 12,000,000, against 330,000,000 in this country. Most of the Russian lines have a government guarantee of from 4½ to 5½ per cent. interest, and the actual dividends paid on the shares amounted in 1870 to from 5 to 7½ per cent. Two lines only seem eminently profitable, viz.: the Moscow-Riazan line, which gave 17½ per cent., and the Koursk-Kiew line, which gave 31¼ per cent. The concession to the companies is generally for from 70 to 80 years. Very few lines now belong to the State. To Russia the railways are of the greatest possible advantage. From Moscow, the central *reseau*, you may now travel east as far as the Oural mountains, north to St. Petersburg, west to Kœnigsberg, and Warsaw, and south to Odessa, Sevastopol, and Astrakhan. And it is even contemplated eventually to extend the railway across the Oural mountains, through Siberia, to China. Yet I doubt whether railway property will be profitable in Russia for many years to come, whatever be the ultimate result. The mass of the population in Russia are too poor to travel —they are not accustomed to it; the passport system interferes with it. There is nothing, moreover, to feed the lines midway, so few are the centres of population and traffic. And Russian produce consists mostly of grain and other bulky articles, which can not stand much freight, and can as well be transported by water communication. It should be remembered that excellent means of communication exist in Russia in her enormous rivers and lakes. The Vistula, at Warsaw, looked beautiful, and the Volga, which we passed near Moscow, is more than ten times the length of the Thames. There is a canal communication, moreover, between St. Petersburg and the Caspian Sea, between the Baltic and the Black Sea, and between the White Sea and the Caspian. Only it is unfortunate that all the canals, lakes, and rivers, aye, even the seas of Russia, are closed by the ice for about seven months in the year. How important, then, to extend the railway system into the very heart of the country. In winter the railway must of necessity monopolize the whole traffic of the country.

It was a long way between Warsaw and St. Petersburg, requiring at least thirty hours of constant journeying, so we determined to rest at Wilna, the chief town of the ancient Duchy of Lithuania; but how poor did she seem to be! Wilna is well situated in the hollow at the foot of several hills, and contains many objects of interest; but, as a rule, the towns and villages of Russia are poor and badly built. The houses are mostly of wood; the streets wretchedly paved. In many cases, moreover, the towns are not the spontaneous result of trade and industry, but the capricious plantations of administrators or military officers. The only towns of any importance in Russia are St. Petersburg, Moscow, Warsaw, Odessa, and Riga. In 1867 the entire population of the Russian Empire was not less than 82,000,000, and of this probably less than 5,000,000 was urban population. But why should St. Petersburg be the capital of Russia? Some cities have become capitals from the fact that the sovereign from time immemorial resided in them. Some owe their position to their favorable situation, and some to the fact of their containing the largest number of persons. St. Petersburg can claim neither of these titles. She is at the very extremity of the empire; she has none of the prestige which Moscow possesses, and she has but a small proportion of the population of the kingdom. While London has about 100 persons to every 1,000 of the population of the kingdom; Lisbon, 61; Copenhagen, 59; Athens, 55; Dresden, 55; Paris, 45; Berlin, 27; Constantinople, 22; Vienna, 14; St. Petersburg has only 7 to the 1,000. St. Petersburg is the capital of Russia simply because Peter the Great willed it; but a force greater than that of the emperor points to Moscow as the natural centre. But St. Petersburg is doubtless a beautiful city. As we entered the station in St. Petersburg an officer from the Congress communicated to us that the municipality offered to us its hospitality; that hotels had been provided for the convenience of members, and carriages placed at our disposal, so we drove at once to the Hotel Bellevue, on the Newski Prospect. And what a sight was before us in that street, more than three miles in length, full of bustle and animation. As a city St. Petersburg stands in favorable comparison

with Berlin for life and cheerfulness. The magnificent Neva, which winds through the town, is infinitely superior to old Father Thames, though no forest of masts meet you at any of the quays. A pure sky and a dry atmosphere are preferable to our everlasting damp and fog. The low drowskies, with Ivan ever at hand, carry you over the otherwise tumble-down pavement with the greatest celerity. Something out of the common-place civilization of Paris and London meets you at every corner.

It was the 21st of August when we arrived at St. Petersburg, where we found the temperature warm and genial. The thermometer was from 65 to 70 in the shade, and otherwise the climate was clear and dry; yet now and then we felt extremely cold; and I understand that, owing to such variations, the climate is very trying to health. Hence the general habit of wearing long heavy coats and closed up dresses at all times; hence the hermetically shut up windows and doors in the warmest days. But I have not seen St. Petersburg in winter, when the Neva is frozen, when snow and ice take possession of her streets for months together, when the drowsky is replaced by the sledge; when the fur clothing, the fur collar and sable hat, constitutes the costume of ladies and gentlemen. The temperature in Russia is regulated more by the longitude than by the latitude. The more eastward we go the greater is the difference between the temperature of summer and winter.

In matters of food and drink we had little difficulty. Our first care was to eschew altogether the water of the Neva, which, containing a certain quantity of magnesia, generally proves relaxing, especially to strangers. But, otherwise, no better food could be had than was supplied to us at the principal hotels. Our rouble dinner at the Bellevue was superior to any three-shilling dinner in London, and the wine was excellent. At a dinner at Moscow we had different descriptions of Russian wines, principally from the Crimea, and they were much appreciated. Mr. Beckwith, in his excellent report on fermented drinks at the Paris exhibition, said that the white wines of the Crimea are clear and dry, with a slight muscatel flavor and good body; and the red resembles very old port, bereft, however, of its strength. In Mr. Beckwith's opinion these wines are very suitable to our climate. M. Tegobonski gave the production of wine at about 42,000,000 gallons, of which 8,000,000 come from the province of Stravropol, 8,000,000 in Bessarabia, 22,000,000 gallons in the Trans-Caucasian provinces, and the rest in the Crimea, the Cossacks, Khenan, Podolia, and Astrakhan. In Russia, Germany, and other northern countries, the people generally eat black rye bread—very uninviting, but remember that, with the dryness of the climate, a portion of black bread, and other elements containing vegetable acids, are absolutely necessary to prevent scrofula, more especially among young people.

But we must regard Russia this evening from an industrial and not from an æsthetic aspect, and in so doing we must guard ourselves from considering the industries of Russia as limited entirely to the urban population. On the contrary, there are villages in Russia in which all the peasants are weavers, tanners, shoemakers, locksmiths, cutlers, &c. In Russia the peasant works for the manufacturer without quitting the village, and carries on himself the chief part of the commerce of the interior. I was informed that there is no peasantry more hard working than the Russian pease antry, and that the women are constantly employed not only in household duties, but in agricultural work, in weaving, bleaching, and many things which in England are done by machinery in factories and in manufacturing towns. Primarily, no doubt, Russia in an agricultural and not a manufacturing country. But, after all, agriculture is the greatest source of wealth to any country. England is by far the most industrious and the most mercantile country in the world. She supplies the whole world with her manufactures. She has the largest mercantile marine. Her power rests on her commerce and industry. Yet, with all this, the results of the income-tax show that the income of all her industry is only about equal to her income from her agriculture and real property. Still greater is the supremacy of agriculture in Russia. In truth, Russia is wanting in some of the principal conditions for industrial prosperity.

Look at the map of Russia. She has no sea-coast of any importance. On the far east there are the vast plains of Siberia. On the west she has Eastern Prussia, quite as deserted and agricultural as Russia herself. On the north she has the glacial Pole; on the south none but semi-barbarous states.

Add to this a population almost entirely composed of peasants; no coals in any quantity, or, at any rate, scarcely worked at all; very little capital; and every agent of manufacture extremely dear. What chance can Russia have in commerce and industry in competition with these sea-girt isles, or with well-favored France or Italy? A mill in Russia costs double that of a mill in England. Bricks are dearer and double the quantity is used to render the building substantial; mortar costs double, and so does all machinery. Consequently, but little factory labor is introduced into Russia. What there is, moreover, is to a large extent under the direction of Englishmen, Germans, Alsatians and other foreigners. British directors and overseers manage the best factories. In the south of Russia it is the same. Vice-Consul Stevens, of Nicolaieff, reported that the chief ganger at the granite quarries at Alexandrovka is an Englishman; the director of the extensive Tchemornski sugar factory in Pattawa is the same; so are the superintending engineer of the Russian Steam Navigation Company at Odessa and his assistant; and the company's chief engineer in the Don mines; the one at Sevastopol; their boiler-master, their master-painter, and the heads of other departments are also Englishmen. The English, the French, the Germans, and the Greeks have a large share in the direction of Russian trade and industry. The Russian mind wants in power and in originality. It is better able to execute, than to direct—to imitate, rather than to lead. I visited a cotton printing factory in Moscow directed by an Alsatian, and I found that the laborers were Russian peasants who come from the country when agricultural labor is impracticable, to recruit the earnings of the family. Such peasants are usually hired in gangs, the head of which assumes the management of the expenditure of the whole number. They live, I need not say, at very small cost, and at any time labor ceases in towns, they return to the country. There are not in Russia as in this country, millions of mechanics, spinners, or miners depending for their livelihood on the buoyancy of trade and manufacture. There is rather an intermingling of agricultural and industrial labor, and consequently an utter absence of the artisan class, the precarious existence of which we have so often to lament in this country.

But let us enter into some details. The first article of industry which naturally interests this country is cotton. Cotton is not produced in Russia, and her imports of 1867 consisted of about 2,600,000 poods, or about 100,000,000lbs. of raw cotton, and 150,000 poods of cotton yarn. Mr. Lumley, in his report of the trade and manufacture of cotton in Russia, gave the number of cotton spinning and calico weaving manufactories in the government of St. Petersburg in 1862, at 95, with 1,691,224 spindles, 16,141 power looms, and 8,040 horse power; and Mr. Michel, in his valuable report on the Russian tariff, told us that the whole quantity of cotton yarn manufactured in Russia is used as follows:—1,400,000 poods for printed calico, 200,000 poods for nankeen, red fustian, and Turkey red goods; 100,000 poods for plush, and the remaining 500,000 poods for various other cotton and half-cotton fabrics. Russian spinneries supply the weaving mills with yarn of low and medium quality; foreign yarn is alone employed for cotton tissue of superior description, such as fine calico, jacconet and muslin. The manufacture of the common kinds of cotton fabrics, namely, calico, nankeen, red fustian, and handkerchiefs, intended chiefly for dyeing and printing, forms a branch of peasant industry, supported by the capital of manufacturers in towns and particularly by that of the owners of print-works. The consumption of cotton goods in Russia must be large. Supposing 60,000,000 peasants to consume 10 archines, or about 8 yards each, that would give about 480,000,000 yards. Add to this the consumption of 5,000,000 urban population at 20 archines each, or 15 yards each, 75,000,000 yards more, and we have a total of upwards of 550,000,000 yards. Yet, in the face of all this, all our exports of cotton to Russia in 1871 consisted only of 3,477 lbs. yarn, and 140,000 yards of goods of mixed materials in which cotton predominated. Why do we not supply Russia more largely with our staple manufacture? Partly in consequence of a very high tariff, and partly also from want of adaptation of British goods to the tastes and habits of the many races and nationalities residing in Russia. The tariff was somewhat reduced in 1868, the duties on cotton yarn from 16 to 20 per cent., and the duties on cotton manufactures from 22 to 27 per cent.; but still the present duties on the latter, of from £5 10s. to £23 12s. 11d. per cwt., must be

considered as practically prohibitive. I shall not weary you with any description of the condition of other industries--of woollen, flax (on which I wished to make mention of Dr. Collier's new treatment), of leather, tallow, and metals—because, in reality, they are more or less governed by the same general circumstances.

Mr. Michel gives the following summary of Russian manufacturing industry :—

Nature of industry.	No. of works and mnf'tories	Number of workmen.	Value of production in roubles.
Cotton.....	606	69,347	71,725,459
Hemp and flax..	225	22,259	11,405,686
Woollen.....	614	92,322	22,565,518
Silk	292	7,933	4,438,421
Dye Works.....	204	3,919	4,196,603
Paper	170	13,203	5,275,816
Leather	2,471	13,245	18,164,897
Tallow.....	1,595	10,566	22,553,255
Wax.....	216	1,083	2,722,624
Pottery	289	4,178	1,321,078
Glass.....	210	10,744	4,402,774
Metals	713	47,379	28,688,124
Chemicals.....	377	6,136	23,193,817
	7,982	302,314	220,654,072 *

Distillation of 27,000,000 vedros of pure spirits, equal to about 73,000,000 gallons.
Beer and mead brewed, 7,900,000 vedros, equal to about 21,000,000 gallons.
Beet-root sugar produced, 3,300,000 poods.
Tobacco manufactured, 594,000 poods.
Iron raised, 15,781,000 poods.

One important element should not be omitted in any review of Russian industry. It is the possibility that ere long considerable quantities of coal may be obtained in different parts of the country. In the Don district the increase has been remarkable:

In 1820	there	were	produced,	350
1840	"	"	"	800,000
1847	"	"	"	2,860,000
1863	"	"	"	6,350,000

The Moscow Exhibition gave evidence of the existence of coal in considerable quantity.

For the commerce of Russia St. Petersburg is by far the most important outpost, though Moscow is the centre of Russian industry. In both places there is evidence that the general movement of trade is extending rapidly. In 1859 the entire value of imports and exports amounted to 329,000,000 roubles. In 1869 it reached 592,000,000 roubles. Among the exports, grain, hemp, and flax are by far the most important. Among the imports, cotton and metals stand foremost. An important change is observable in the foreign commerce of Russia, in consequence of the extension of railways. In 1859 the foreign exports by sea amounted to 130,000,000 roubles, and by land, to 22,000,000 roubles, or about 16 per cent. In 1869 the exports by sea amounted to 190,000,000, and by land 95,000,000, or 50 per cent. While bulky goods are sent by sea, lighter goods penetrate by land, chiefly from Prussia and through the Prussian frontier. It should be noted here that, while the commerce of Russia with European States has largely increased, her commerce with Asia has actually decreased of late. The Asiatic portion of the Russian trade is small as compared with the European, and yet considerable interest attaches to it, first on account of the primitive manner in which it is still conducted, and secondly, in consequence of the intimate relation which exists between the extension of trade and the constant enlargement of the Russian empire. By incorporating Turkestan, Russia has come very near British India, and now she has commercial treaties with the Khan of Khokand and the Ameer of Bokhara and Dschiti Tchar. But what does it matter by what influence it is brought about, provided these States are rendered accessible to trade and civilization ?

Being in a certain sense the guests of the Emperor of all the Russias and of his august government, we were honored with numerous invitations to receptions and excursions. One day we went to Cronstadt and Peterhoff. Another day we had a sail round the islands, and were entertained in one of the palaces of the Princess Helena, which at night was beautifully illuminated. What we most appreciated in these receptions was not so much the sumptuousness of the entertainments, as the consideration shown in making us what the English think they alone understand, but what other nations know quite as well—I mean "comfortable." To put us at ease—to anticipate our wants—to endeavor to speak our language—to put every individual and every thing in the right place, that is the perfection of hospitality.

The grandest excursion of all, however, was to Moscow, whose municipality was as courteous as that of St. Petersburg in supplying members of Congress with hotel accommodation and carriages during their stay in the city. At first sight Moscow is by no means attractive. It seems an old city, badly paved, and with irregular buildings. But from such a height as the Sparrow

* Equal to about £30,000,000.

hill—the very ground whence Napoleon obtained his first glance of Moscow—the sight of the golden minarets and starry domes before you is quite unique and startling. According to arrangement, we visited the Polytechnic Exhibition at Moscow, an excellent one of its kind. I was not able to inspect it with any care or minuteness, especially as we visited the exhibition in great numbers, but it was apparent, first that Russian industry is by no means in such a backward state as is generally supposed; and, second, that British industry was most imperfectly represented. The exhibition—consisting of a number of pavilions alongside the garden of the Kremlin—did not seem to have much unity, while it was altogether destitute of a general *coup-d'œil;* yet it possessed many objects of great interest and attraction, and day by day we saw it visited by large numbers of people.

At Moscow, as well as at St. Petersburg, but more especially in the latter place, I found British merchants of the highest respectability, numbering in all probably some 3,000, the living representatives, I suppose, of the Russia Company with its agency at St. Petersburg, under the title of the British factory, founded by charter of Philip and Mary, about 300 years ago. The original charter confirmed by Act of Parliament granted that, "All the main lands, isles, ports, havens, creeks, and rivers of the mighty Emperor of all Russia and Great Duke of Musky, &c., and all and singular other lands dominions, territories, isles, ports, havens, creeks, rivers, arms of the sea, and all and every other prince, ruler, or governor whatsoever, be or they be before the said late adventure or enterprise not known, or by the foresaid merchants and subjects of the said King and Queen by the seas not commonly frequented, nor any part or parcel thereof, and lying northward, northeastward, or northwestward, or in the said letters patent is mentioned, should not be visited, frequented, nor haunted by any of the subjects of the late King and Queen other than of the said company and fellowship and their successors, without express license, agreement, and consent of the governors, consuls, assistants of the said fellowships and commonalty." That no such permission is now required to trade in Russia is well known, yet, singular to say, charges are still made by the Russia factory on British shipping using the port of St. Petersburg or Cronstadt, being first a charge of 3½d. per ton for the maintenance of the British Episcopal Establishment at that place and in aid of the poor's fund, and, second, a charge under the head of Company's Agent, which amounts to $1\frac{1}{10}$d. per ton. A few years ago some effort was made by the Hull Chamber of Commerce to procure the abolition of these charges, when it appeared that the tonnage duty, denominated church money, amounted, on an average, to only £2,200 per annum, and the agent's only to £956. But the charge, though light, is not less condemnable. The British factory has, in reality, long ceased to exist or to be needful; and I imagine that the British merchants in St. Petersburg, or such of them as are Episcopalians, should themselves pay for the church, and that the British government should pay for the agency, without taxing trade and shipping for such purposes. Generally, I need scarcely say, English merchants in Russia are as safe and protected as if they were in England. It should be remembered that the government of Russia now is not the arbitrary government that it was in former days. True, the Czar is autocrat absolute, but he does not act alone, and far less capriciously. He has a council of responsible ministers; he has a House of Lords, of his own creation, doubtless, but yet able and willing to render him advice; he has a holy synod, and he has governors in every province, able to feel the pulse of public opinion, and with full power to meet the exigencies of the moment. And do not think that public opinion does not find itself vent in Russia. There are newspapers in Russia, though much under the power of the State. The silent protest under wrongs, the murmurs of the oppressed, the aspirations of the enlightened, can not be smothered even in Russia. But in truth Russia is tranquil at this moment, and the Emperor has the heart of the people with him. Nowhere did I see any parade of military force, as we are wont to see in turbulent Paris or in imperial Berlin. As for the people, it is, I fear, as yet in a low condition. The mass of the peasantry recently emancipated has scarcely risen from the position of serfdom. The industrial classes are ill-paid, ill-fed, and in the depth of ignorance. The middle classes scarcely exist in Russia. The nobles do not exercise much wholesome influence. The priests hold an inferior position to what we are accustomed to in this country. Something is, however, done for the

education of the people. There are nine universities, three lyceums, 23,000 schools, and nearly 1,000,000 students in the public schools in Russia. The freedom of serfdom is a most significant fact, the fruit of which will one day appear. What may be the future of the Russian people, when free and educated, we cannot say. Meanwhile, trade is increasing, the country is progressing, and the railway opens up the country in a wonderful manner. As far as I can see, I venture to say the Russia of the future will be far different in power and enlightenment, in commerce and industry, from the Russia of the past.

Ere I close, permit me to express my own sense and the sense of every foreign member of the International Statistical Congress, of the kindness shown us by the Russian government on the occasion of our visit to Russia. Would that England received in like manner men of science from other countries when they come to her soil. It would be well if her example were more conspicuous for a liberal expenditure than for a niggard economy in all matters which concern the promotion of science and art. Would that the same coöperation on the part of the officers of State could be secured for the meeting of scientific congresses in London as is so readily obtained in other countries. Perhaps it may not be in vain that her messengers to Russia, to Italy, to Holland, and to every state where the International Statistical Congress has been held, are able to report that a reception the most courteous, the most hospitable, the most considerate, is everywhere accorded to men of science when they meet together for the elucidation of great questions, either of social economy or of scientific importance.

THE ORIGIN OF METALLIFEROUS DEPOSITS.

By T. STERRY HUNT, LL. D., F. R. S.

From the transactions of the American Institute of Mining Engineers.

There are about sixty bodies which chemists call elements; the simplest forms of matter which they have been able to extract from the rocky crust of our earth, its waters and its atmosphere. These substances are distributed in very unequal quantities, and in very different manners. As regards the frequency of these elements in nature, neglecting for the present those which constitute air and water, and confining ourselves to the solid matters of the earth's crust, there are a few which are exceedingly abundant, making up nine-tenths if not ninety-five hundredths, of the rocks so far as known to us. The elements of which silica, alumina, lime, magnesia, potash and soda are oxides, are very common, and occur almost everywhere. There are others which are much rarer, being found in comparatively small quantities. Many of these rarer elements, are, however, of great importance in the economy of nature. Such are the common metals and other substances used in the arts, which occur in nature in quantities relatively very minute, but which have been collected by various agencies, and thus made available for the wants of man. It is chiefly of the well-known metals, iron, copper, silver and gold, that I propose to speak to-night; but there are two other elements not classed among the metals, which I shall notice for the reason that their history is extremely important, and will, moreover, enable us to comprehend more clearly some points in that of the metals themselves. I speak of phosphorus and iodine.

You all know the essential part which the former of these, combined as phosphate of lime, plays in the animal economy, in the formation of bones; and how plants require for their proper growth and development a certain amount of phosphorus. Ordinary soils contain only a few thousandths of this element, yet there are agencies at work in nature which gather this diffused phosphorus together in beds of mineral phosphates and in veins of crystalline apatite, which are now sought to enrich impoverished soils. Iodine, an element of great value in medicine and in the art of photography, is widely distributed, but still rarer than phosphorus, yet it abounds in certain mineral waters, and is, moreover, accumulated in marine plants. These extract it from the waters of the sea, where iodine exists in such minute quantities as almost to elude our chemical tests.

There are probably no perfect separations in nature. We cannot, without great precautions, get any chemical element in a state of absolute purity, and we have reason to believe that even the rarest elements are everywhere diffused in infinitesimal quantities. The spectroscope, which we have lately learned to apply to the investigation alike of the chemistry of our own earth and that of other worlds once supposed to be beyond the chemist's ken, not only demonstrates the very wide diffusion of various chemical elements here on earth, but shows us that very many of them exist in the sun. If we accept, as most of us are inclined to do, the nebular hypothesis, and admit that our earth was once, like the sun of to-day, an intensely heated vaporous mass; that it is, in fact, a cooled and condensed portion of that once great nebula of which the sun is also a part, we might expect to find all the elements now discovered in the sun distributed throughout this consolidated globe. We may speculate about the condensation of some of these before others, and their consequent accumulation in the inner parts of the earth, but the fact that we have all the elements of the solar envelope (together with many more) in the exterior portions of our planet, shows that there was, at least, but a very partial concentration and separation of these elements during the period of cooling and condensation. The superficial crust of the earth, from which all the rocks and minerals which we know have been generated, must have contained, diffused through it, from the earliest time, all the elements which we now meet with in our study of the earth, whether still diffused, or accumulated, as we often find the rarer elements, in particular veins or beds.

The question now before us is, how have these elements thus been brought together, and why is it that they are not all still widely and universally diffused? Why are the compounds of iron in beds by themselves, copper, silver and gold gathered together in veins, and iodine concentrated in a few ores and certain mineral waters? That we may the better discern the direction in which we are to look for the solution of this problem, let us premise that all of these elements, in some of their combinations, are more or less soluble in water. There are, in fact, no such things in nature as absolutely insoluble bodies, but all, under certain conditions, are capable of being taken up by water, and again deposited from it. The alchemists sought in vain for a universal solvent, but we now know that water, aided in some cases by heat, pressure, and the presence of certain widely distributed substances, such as carbonic acid and alkaline carbonates and sulphides, will dissolve the most insoluble bodies; so that it may after all be looked upon as the long-sought-for alkahest or universal menstrum.

Let us now compare the waters of rivers, seas, and subterranean springs, thus impregnated with various chemical elements, with the blood which circulates through our own bodies. The analysis of the blood shows it to contain albuminoids which go to form muscle, fat for the adipose tissues, phosphate of lime for the bones, fluorides for the enamel of the teeth, sulphur, which enters largely into the composition of the hair and nails, soda, which accumulates in the bile, and potash, which abounds in the flesh-fluid. All of these are dissolved in the blood, and the great problem for the chemical physiologist is to determine how the living organism gathers them from this complex fluid, depositing them here and there, and giving to each part its proper material. This selection is generally ascribed to a certain vital force, peculiar to the living body. I shall not here discuss the vexed question of the nature of the force which determines the assimilation from the blood of these various matters for the needs of the animal organism, further than to say that modern investigations tend to show that it is only a subtler kind of chemistry, and that the study of the nature and relation of colloids and crystalloids, and of the phenomena of chemical diffusion, promises to subordinate all these obscure physiological processes to chemical and physical laws.

Let us now see how far the comparison which we have made between the earth and an animal organism will help us to understand the problem of the distribution of minerals in nature; how far water, the universal solvent, acting in accordance with known chemical and physical laws, will cause the separation of the mixed elements of the earth's crust, and their accumulation in veins and beds in the rocks. The subject is one of great importance to the geologist, who has to consider the genesis of the various rocks and ore-deposits, and the relations, which we are only beginning to un-

der-tand, between certain metels and particular rocks, and between certain classes of ores and peculiar mineralogical and geological conditions. It is at the same time a vast one, and I can to-night only give you a few illustrations of the chemistry of the earth's crust, and of the laws of the terrestrial circulation, which I have compared to that of the blood distributing throughout the animal frame the elements necessary for its growth. The analogy is not altogether new, since a great French geologist, Elie de Beaumont, has already spoken of a terrestrial circulation in regard to certain elements in the earth's crust; though he has not, so far as I am aware, carried it out to the extent which I propose to-night in my attempt to explain some of the laws which have presided over the distribution of metals in the earth.

The chemist in his laboratory takes advantage of changes of temperature, and of the action of various solvents and precipitants, to separate, in the humid way, one element from another; but to these agencies, in the economy of nature, are added others which we have not yet succeeded in imitating, and which are exerted only in growing animals and plants. I repeat it, I do not wish to say that these latter processes are different in kind from those which we command in our laboratories, but rather that these organisms control a far finer and more delicate chemical and physical apparatus than we have yet invented. Plants have the power of selecting from the media in which they live the elements necessary for their support. The growing oak and the grass alike assimilate from the air and water the carbon, hydrogen, nitrogen, and oxygen which build up their tissues, and at the same time take from the soil a portion of phosphorous, which, though minute, is in both cases essential to the vegetable growth. The acorn of the oak and grass alike become the food of animals, and the gathered phosphates pass into their bones, which are nearly pure phosphate of lime. In like manner the phosphates from organic waste and decay find their way to the sea, and through the agency of marine vegetation become at last the bony skeletons of fishes. These are, in turn, the prey of carnivorous birds, whose exuviæ form on tropical islands beds of phosphatic guano. A history not dissim lar will explain the origin of beds of coprolites and other deposits of mineral phosphates.

But again, these plants or these animals may perish in the sea and be buried in its ooze. The phosphates which they have gathered are not lost, but become fixed in an insoluble form in the clayey matter; and when in the revolutions of ages, these sea-muds, hardened to rock, become dry land, and crumble again to soil, the phosphates are there found ready for the wants of vegetation.

Most of what I have said of phosphates applies equally to the salts of potash, which are not less necessary to the growing plant. From the operation of these laws it results that neither of these elements is found in large quantities in the ocean. This great receptacle of the drainage from the land contains still smaller quantities of iodine; in fact, the traces of this element present in sea-water can scarcely be detected by our most delicate tests. Yet marine plants have the power of separating this iodine, and accumulating it in their tissues, so that the ashes of these plants are not only rich in phosphates and in potash-salts, but contain so much iodine that our supplies of this precious element are almost wholly derived from this source, and that the gathering and burning of sea-weed for the extraction of iodine is in some regions an important industry. When this marine vegetation decays, the iodine which it contains, appears, like the potash and phosphates, to pass into combinations with metals, earths, or earthy phosphates, which retain it in an insoluble state, and in certain cases yield it to percolating saline solutions, which thus give rise to springs rich in iodine.

In all of these processes, the action of organic life is direct and assimilative, but there are others in which its agency, although indirect, is not less important. I can hardly conceive of an accumulation of iron, copper, lead, silver, or gold, in the production of which animal or vegetable life has not either directly or indirectly been necessary, and I shall begin to explain my meaning by the case of iron. This, you are aware, is one of the most widely diffused elements in nature; all soils, all plants contains it; and it is a necessary element in our blood. Clays and loams contain, however, at best, two or three hundredths of the metal, but so mixed with other matters that we could never make it available for the wants of

this iron age of ours. How does it happen that we also find it gathered together in great beds of ore, which furnish an abundant supply of the metal? The chemist knows that the iron, as diffused in the rocks, exists chiefly in combination with oxygen, with which it forms two principal compounds; the first, or protoxide, which is readily soluble in water impregnated with carbonic acid or other feeble acids, and the second, or peroxide, which is insoluble in the same liquids. I do not here speak of the magnetic oxide, which may be looked upon as a compound of the other two, neutral and indifferent to the most natural chemical agencies. The combinations of the first oxide are either colorless or bluish or greenish in tint, while the peroxide is reddish-brown, and is the substance known as iron-rust. Ordinary brick-clays are bluish in color, and contain combined iron in the state of protoxide, but when burned in a kiln they become reddish, because this oxide absorbs from the air a further proportion of oxygen, and is converted into peroxide. But there are clays which are white when burned, and are much prized for this reason. Many of these were once ferruginous clays, which have lost their iron by a process everywhere going on around us. If we dig a ditch in a moist soil which is covered with turf or with decaying vegetation, we may observe that the stagnant water which collects at the bottom soon becomes coated with a shining, iridescent scum, which looks somewhat like oil, but is really a compound of peroxide of iron. The water as it oozes from the soil is colorless, but has an inky taste from dissolved protoxide of iron. When exposed to the air, however, this absorbs oxygen, and peroxide is formed, which is no longer soluble, but separates as a film on the surface of the water, and finally sinks to the bottom as a reddish ochre, or, under somewhat different conditions, becomes aggregated as a massive iron ore. A process identical in kind with this has been at work at the earth's surface ever since there were decaying organic matters, dissolving the iron from the porous rocks, clays, and sands, and gathering it together in beds of iron ore or iron ochre. It is not necessary that these rocks and soils should contain the iron in the state of protoxide, since these organic products (which are themselves dissolved in the water) are able to remove a portion of the oxygen from the insoluble peroxide, and convert it into the soluble protoxide of iron, being themselves in part oxidized and converted into carbonic acid in the process.

We find in rock formations of very different ages beds of sediments which have been deprived of iron by organic agencies, and near them will generally be found the accumulated iron. Go into any coal region, and you will see evidences that this process was at work when the coal-beds were forming. The soil in which the coal-plants grew has been deprived of its iron, and when burned turns white, as do most of the slaty beds from the coal-rocks. It is this ancient soil which constitutes the so-called fire-clays, prized for making fire-bricks, which, from the absence of both iron and alkalies, are very infusible. Interstratified with these we often find, in the form of ironstone, the separated metal; and thus from the same series of rocks may be obtained the fuel, the ore, and the fire-clay.

From what I have said it will be understood that great deposits of iron ore generally occur in the shape of beds; although waters holding the compounds of iron in solution have, in some cases, deposited them in fissures or openings in the rocks, thus forming true veins of ore, of which we shall speak further on. I wish now to insist upon the property which dead and decaying organic matters possess of reducing to protoxide, and rendering soluble, the insoluble peroxide of iron diffused through the rocks; and reciprocally the power which this peroxide has of oxidizing and consuming these same organic matters, which are thereby finally converted into carbonic acid and water. This last action, let me say in passing, is illustrated by the destructive action of rusting iron fastenings on moist wood, and the effect of iron-stains in impairing the strength of linen fibre.

We see in the coal formation that the vegetable matter necessary for the production of the iron-ore beds was not wanting; but the question has been asked me, where are the evidences of the organic material which was required to produce the vast beds of iron ore found in the ancient crystalline rocks? I answer, that the organic matter was, in most cases, entirely consumed in producing these great

results; and that it was the large proportion of iron diffused in the soils and waters of those early times, which not only rendered possible the accumulation of such great beds of ore, but oxidized and destroyed the organic matters which in later ages appear in coals, lignites, pyroschists, and bitumens. Some of the carbon of these early times is, however, still preserved in the form of graphite, and it would be possible to calculate how much carbonaceous material was consumed in the formation of the great iron-ore beds of the older rocks, and to determine of how much coal or lignite they are the equivalents.

In the course of ages, however, as a large proportion of the once diffused iron-oxide has become segregated in the form of beds of ore, and thus removed from the terrestrial circulation, the conditions have grown more favorable for the preservation of the carbonaceous products of vegetable life. The crystalline magnetic and specular oxides, which constitute a large proportion of the ores of this metal, are almost or altogether indifferent to the action of organic matter. When, however, these ores are reduced in our furnaces, and the resulting metal is exposed to the oxidizing action of a moist atmosphere, it is again converted into iron-rust, which is soluble in water holding organic matters, and may thus be made to enter once more into the terrestrial circulation.

There is another form in which iron is frequently concentrated in nature, that of sulphide, and most frequently as the bi-sulphide known as iron-pyrites. This substance is found both in the oldest and the newest rocks, and, like the oxide of iron, is even to-day forming in certain waters, and in beds of mud and silt, where it sometimes takes a beautifully crystalline shape. What are the conditions in which the sulphide of iron is formed and deposited, instead of the oxide or carbonate of iron? Its production depends, like these, on decaying organic matters. The sulphates of lime and magnesia, which abound in sea-water, and in many other natural waters, when exposed to the action of decaying plants or animals, out of contact of air, are, like peroxide of iron, deoxidized, and are thereby converted into soluble sulphides; from which, if carbonic acid be present, sulphuretted hydrogen gas is set free. Such soluble sulphides, or sulphuretted hydrogen, are the reagents constantly employed in our laboratories to convert the soluble compounds of many of the common metals, such as iron, zinc, lead, copper, and silver, into sulphides, which are insoluble in water and in many acids, and are thus conveniently separated from a great many other bodies. Now, when in a water holding iron-oxide, sulphates are also present, the action of organic matter, deoxidizing the latter, furnishes the reagent necessary to convert the iron into a sulphide; which in some conditions, not well understood, contains two equivalents of sulphur for one of iron, and constitutes iron-pyrites. I may here say that I have found that the unstable protosulphide, which would naturally be first formed, may, under the influence of a persalt of iron, lose one-half of its combined iron; and that from this reaction a stable bi-sulphide results. This subject of the origin of iron-pyrites is still under investigation.

The reducing action of organic matters upon soluble sulphates is well seen in the sulphuretted hydrogen which is evolved from the stagnent sea-water in the hold of a ship, and which coats silver exposed to it with a black film of sulphide of silver, and for the same reason discolors white-lead paint. The presence of sulphur in the exhalations from some other decaying matters is well known, and in all these cases a soluble compound of iron will act as a disinfectant, partly by fixing the sulphur as an insoluble sulphide. Silver coins brought from the ancient wreck of a treasure-ship in the Spanish Main were found to be deeply incrusted with sulphide of silver, formed in the ocean's depths by the process just explained, which is one that must go on wherever organic matters and sea-water are present, and atmospheric oxygen excluded.

The chemical history of iron is peculiar; since it requires reducing matters to bring it into solution, and since it may be precipitated alike by oxidation, and by farther reduction, provided sulphates are present. The metals copper, lead, and silver, on the contrary, form compounds more or less soluble in water, from which they are not precipitated by oxygen, but only by reducing agents, which may separate them in some cases in a metallic state,

but more frequently as sulphides. The solubility of the salts and oxides of these metals in water is such that they are found in many mineral springs, in the waters that flow from certain mines, and in the ocean itself, the waters of which have been found to contain copper, silver, and lead. Why, then, do not these metals accumulate in the sea, as the salts of soda have done during long ages? The direct agency of organic life comes again into play, precisely as in the case of phosphorus, iodine, and potash. Marine plants, which absorb these from the sea-water, take up at the same time the metals just named, traces of all of which are found in the ashes of sea-weeds. Copper, moreover, is met with in notable quantities in the blood of many marine molluscous animals, to which it may be as necessary as iron is to our own bodies. Indeed, the blood of man, and of the higher animals, appears never to be without traces of copper as well as of iron.

In the open ocean the waters are constantly aerated, so that soluble sulphides are never formed, and the only way in which these dissolved metals can be removed and converted into sulphides is by fixing them in organisms, either vegetable or animal. These, by their decay in the mud of the bottom, or the lagoons of the shore, generate the sulphides which fix their contained metals in an insoluble form, and thus remove them from the terrestrial circulation.

It is not, however, in all cases necessary to invoke the direct action of organisms to separate from water the dissolved metals. It often happens that the waters containing these, instead of finding their way to the ocean, flow into lakes or inclosed basins, as in the case of the drainage-waters of an English copper-mine, which have impregnated the turf of a neighboring bog to such an extent that its ashes have been found a profitable source of copper. Under certain conditions, not yet well understood, this metal is precipitated by organic matters in the metallic state, but if sulphates are present a sulphide is formed. Thus, in certain mesozoic schists in Bohemia, sulphide of copper is found incrusting the remains of fishes, and in the sandstones of New Jersey we find it penetrating the stems of ancient trees. I have in my possession a portion of a small trunk taken from the mud of a spring in Ontario, in which the yet undecayed wood of the centre is seen to be incrusted by hard metallic iron-pyrites. In like manner the old trees of the New Jersey sandstone became incrusted with copper-sulphide, which, as decay went on, in great part replaced the woody tissue. Similar deposits of copper and of iron often took place in basins where the organic matter was present in such a condition or in such quantity as to be entirely decomposed, and to leave no trace of its form, unlike the examples just mentioned. In this way have been formed fahl-bands, and beds of pyrites and other ores.

The fact that such deposits are associated with silver and with gold leads to the conclusion that these metals have obeyed the same laws as iron and copper. It is known that both persalts of iron and soluble sulphides have the power of rendering gold soluble, and its subsequent deposition in the metallic state is then easily understood.

I have endeavored by a few illustrations to show you by what processes some of the more common metals are dissolved and again separated from their solution in insoluble forms. It now remains to say somewhat of the geological relations of ore deposits, which are naturally divided into two clauses; the first including those which occur in beds, and have been formed contemporaneously with the inclosing earthy sediments. Such are the beds of iron-ores which often hold imbedded shells and other organic remains, and the copper-bearing strata already mentioned, in which the metal must have been deposited during the decay of the animal or plant which it incrusts or replaces. But there are other ore deposits evidently of more recent formation than the rocky strata which inclose them, which have resulted from a process of infiltration, filling up fissures with the ore, or diffusing it irregularly through the rock. It is not always easy to distinguish between the two classes of deposits. Thus a fissure may in some cases be formed and filled between two sundered beds, from which may result a vein that may be mistaken for an interposed stratum. Again, a bed may be so porous that infiltrating waters may diffuse through it a metallic ore, or a metal, in such a manner as to leave it doubtful whether the process was contemporaneous with the disposition of the bed, or posterior to it. But I wish to

speak of deposits which are evidently posterior, and occupy fissures in previously formed strata, constituting true veins. Whether produced by the great movements of the earth's crust, or by the local contraction of the rocks (and both of these causes have in different cases been in operation), such fissures sometimes extend to great lengths and depths; their arrangement and dimensions depending very much on the texture of the rocks which have been subjected to fracture. When a bone in our bodies is broken, nature goes to work to repair the fractured part, and gradually brings to it bony matter, which fills up the little interval, and at length makes the severed parts one again. So when there are fractures in the earth's crust, the circulating waters deposit in the openings mineral matters, which unite the broken portions, and thus make whole again the shattered rocks. Vein-stones are thus formed, and are the work of nature's conservative surgery.

Water, as we have seen, is a universal solvent, and the matters which it may bring and deposit in the fissures of the earth are very various. There is scarcely a spar or an ore to be met with in the stratified rocks that is not also found in some of these vein-stones, which are often very heterogeneous in composition. In certain veins we find the elements of limestone or of granite, and these often include the gems, such as amethyst, topaz, garnet, hyacinth, emerald, and sapphire; while others abound in native metals or in metallic oxides or sulphides. The nature of the materials thus deposited depends very much on conditions of temperature and of pressure, which affect the solvent power of the liquid, and still more upon the nature of the adjacent rocks and of the waters permeating them. The chemistry of mineral veins is very complicated. Many of these fissures penetrate to a depth of thousands of feet of the earth's crust, and along the channels thus opened the ascending heated subterranean waters may receive in their course various contributions from the overlying strata. From these additions, and from the diminished solubility resulting from a decrease of pressure, deposits of different minerals are formed upon the walls, and the slow changes in composition are often represented by successive layers of unlike substances. The power of these waters to dissolve and bring from the lower strata their contained metals and spars is probably due in great part to the alkaline carbonates and sulphides which these waters often hold in solution; but the chemical history of the deposition of the ores of iron, lead, copper, silver, tin, and gold, which are found in these veins, demands a lengthened study, and would furnish not less beautiful examples of nature's chemistry than those I have already laid before you.

The process of filling veins has been going on from the earliest ages; we know of some which were formed before the Cambrian rocks were deposited, while others are still forming, as the observations of Phillips have shown us in Nevada, where hot springs rise to the surface and deposit silica, with metallic ores, which incrusts the walls of the fissures. These thermal waters show that the agencies which in past times gave rise to the rich mineral deposits of our Western regions, are still at work there.

Let us now consider the beneficent results of the process of vein making. The precious metals, such as silver, are so sparsely distributed, that even the beds rich in the products of decaying sea-weed, which we have supposed to be deposited from the ocean, would contain too little silver to be profitably extracted. But in the course of ages these sediments, deeply buried, are lixiviated by permeating solutions, which dissolve the silver diffused through a vast mass of rock, and subsequently deposit it in some fissure, it may be in strata far above, as a rich silver ore. This is nature's process of concentration.

We learn from the history which we have just sketched the important conclusion, that amid all the changes of the face of the globe the economy of nature has remained the same. We are apt, in explaining the appearances of the earth's crust, to refer the formation of ore-beds and veins to some distant and remote period, when conditions very unlike the present prevailed, when great convulsions took place, and mysterious forces were at work. Yet the same chemical and physical laws are now, as then, in operation; in one part dissolving the iron from the sediments and forming the ore-beds, in another separating the rarer metals from the ocean's waters; while in still other regions the consolidated and buried sediments are per-

meated by heated waters, to which they give up their metallic matters, to be subsequently deposited in veins. These forces are always in operation, rearranging the chaotic admixture of elements which results from the constant change and decay around us. The laws which the first great cause imposed upon this material universe on the first day are still irresistibly at work fashioning its present order. One great design and purpose is seen to bind in necessary harmony the operations of the mineral with those of the vegetable and animal worlds, and to make all of these contribute to that terrestrial circulation which maintains the life of our mother earth.

While the phenomena of the material world have been looked upon as chemical and physical, it has been customary to speak of those of the organic world as vital. The tendency of modern investigation is, however, to regard the processes of animal and vegetable growth as themselves purely chemical and physical. That this is to a great extent true must be admitted, though I am not prepared to concede that we have in chemical and physical processes the whole secret of organic life. Still we are, in many respects, approximating the phenomena of the organic world to those of the mineral kingdom; and we at the same time learn that these so far interact and depend upon each other that we begin to see a certain truth underlying the notion of those old philosophers who extended to the mineral world the notion of a vital force; which led them to speak of the earth as a great living organism, and to look upon the various changes in its air, its waters, and its rocky depths, as processes belonging to the life of our planet.

[Since this lecture was delivered, I have seen the results of the researches of Sonstadt on the iodine in sea-water, which appear in the "Chemical News" for April 26, May 17, and May 24, 1871. According to him this element exists in sea-water, under ordinary conditions, as iodate of calcium, to the amount of about one part of the iodate in 250,000 parts of the water. This compound, by decaying organic matter (and by most other reducing agents,) is changed to iodide, from which, apparently by the action of carbonic acid, iodine is set free, and may be separated by agitating the water with bisulphide of carbon. The iodine thus liberated from sea-water by the action of dead organic matters, however, slowly decomposes water in presence of carbonate of calcium, and is reconverted into iodate, the oxygen of the air probably intervening to complete the oxidation, since, according to Sonstadt, iodides are readily converted into iodates under these conditions. He finds that the insolubility of the iodides of silver and of copper is so great that by the use of salts of these metals iodine may be separated from sea-water without concentration, provided the iodate of calcium has first been reduced to iodide. By this property of iodine and its compounds to oxidize and be oxidized in turn, Sonstadt supposes them to perform the important function of consuming the products of organic decay, and so maintaining the salubrity of the ocean's waters. Their action would thus be very similar to that of the oxides of iron, as explained in the present lecture.

Still more recently the same chemist has announced that the sea-water of the British coasts contains in solution besides silver an appreciable quantity of gold, estimated by him at about one grain to a ton of water. This is separated by the addition of chloride of barium, apparently as an aurate of baryta adhering to the precipitated sulphate, which yields by assay an alloy of about six parts of gold to four of copper. Other methods have been devised by him for separating these metals from their solution in sea-water. The agent which keeps the gold of the sea in a soluble and oxidized condition is, according to Sonstadt, the iodine liberated by the action already described.

The views maintained by Lieber, Wurtz, Genth, and Selwyn, as to the solution and redeposition of gold in modern alluvial deposits seem to be well grounded, and we are led to the conclusion that the circulation of this metal in nature is as easily effected as that of iron or of copper. The transfer of certain other elements, such as titanium, chrome, and tin, or at least their accumulation in concentrated forms, appears, on the contrary, to require conditions which are no longer operative at the surface of the earth.

It should here be noticed that Prof. Henry Wurtz, of New York, in a paper read before the American Association for the Advancement of Science, in 1868, expressed the opinion that the ocean-waters

contained gold, and urged experiments for its detection. According to his calculations the total amount of gold hitherto extracted from the earth, and estimated at two thousand million dollars, would give only one dollar for two hundred and eighty million tons of sea-water, while from the experiments of Sonstadt, it would appear that the same quantity of gold is actually contained in twenty-five tons of water.]

ON THE IMPORTANCE OF SURVEYING IN GEOLOGY.

By BENJAMIN SMITH LYMAN, C. E.

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The importance of topography to geology is so commonly underrated as to deserve to be pointed out again and again. The relation of topography to the different branches of geology may be seen best by a glance at them all.

Geology is well understood to consist of the observation of facts about rocks as materials of the earth (geognosy), and the explanation of those facts (geogeny).

The facts to observe are:

I. Geometrical, as (1) *structure*, including the dip and strike at different points, the size, shape, and position of basins and saddles; (2) *vertical section*, that is, the thickness of rock groups and of their parts; (3) *horizontal* or geographical *position*.

II. Physical, such as *texture;* whether sedimentary or crystalline; and, if crystalline, whether granitic, porphyritic, amygdaloidal, globular or concretionary; whether *compact or granular; coarse or fine; pervious or impervious: hard or soft; firm or tender; with cleavage or without; massive or thin; the microscopic structure; also, whether magnetic or not; soluble or insoluble; fusible or infusible;* and the *constituent minerals*.

III. Chemical, that is, the composition of the rocks and of their minerals and their affinities.

IV. Palæontological, as what kind of fossils are in the rocks, whether (1) *salt-water;* and if so, whether (*a*) deep water; (*b*) shallow-water; or (*c*) lagoon; (2) *fresh-water;* or (3) *land*.

Knowledge of this general character about the fossils is all that is needed of them for geological purposes, for understanding the nature of the rocks and the successive changes the earth has undergone. The special fossils that may be found in different beds of rock may be of great interest in the history of life in the world, or of organisms (palæontology), and may sometimes give more or less trustworthy aid in determining practically the relative age of such beds, but in general it is rather the position of the beds that determine the relative age of the different groups of animals or plants whose remains are found in them; and geology gives to palæontology far more in value than it gets in return. It is absurd, then, for palæontology to assume to be geology, or the chief part of geology, as so often happens nowadays. Palæontology in truth only helps to a knowledge of a very few of the many physical and chemical facts about the earth's materials, and those few perhaps seldom of very great importance. The explanation of the changes from bed to bed in the general character of the fossils, as salt water, fresh-water, or land, deep-water or shallow-water fossils, depends, of course, on physical or chemical laws.

The facts that were just now called geometrical are, of course, in one sense, merely physical; for they only concern the size, shape, position, and general composition of rocks or groups of rocks. The explanation of such facts must always be of a physical or chemical nature.

It is plain, then, that both the facts of geology and their explanation are always either physical or chemical, with the not very important exception that the general character of fossils is shown by physiology.

The facts learned by measurement, though they can scarcely be separated wholly from the other classes of facts, do not yield to them in importance. The questions, where a rock of a given physical or chemical nature is found, what is its extent, and what is its position relative to other rocks, and to the sea level, are at least as important as the physical and chemical facts themselves, both in theoretical geology and in practical mining. Indeed, the geometrical facts of themselves would some-

times show some of the most important physical facts; as, for example, the shape of the surface of the ground very often shows the relative hardness of the rocks that underlie it, and in a limited region shows by that means what beds of a known series underlie given points, such as a coal-bed marked at its outcrop by a terrace, or a hard bed of rock marked by a ridge. For a thorough understanding of geology, of course, an intimate acquaintance with the laws of physics and chemistry would be needed; but for most practical and even theoretical purposes only that common knowledge of them is wanted which almost every man has, and geometrical measurements become the sole and all-important requirement.

The necessity of some sort of geometrical representation of some of the most important geological facts has been acknowledged almost universally by the use of maps, and of more or less rudely made sections. But it is perhaps the very imperfection of such methods as have been commonly employed, that has brought this branch of geological work into the undeserved contempt in which it seems generally to lie; and such geometrical representation has at best almost always been used solely to set forth geological facts, seldom as a means of finding them out. Very often, indeed, the map is merely to show the geographical distribution of different groups of fossil animals and plants. Even when hills and mountains are shown, it is only by vague shading or indefinite hachure lines with all traces of geological structure left out. The cross-section, with its exaggerated vertical scale and distorted dips, would commonly seem rather to impress the eye with the varying height of surface than to show how the rocks lie, the true aim of a geological section. The map and section not only give the geological facts so very imperfectly, but are almost useless as an aid in working out the geology, from the bare, disconnected facts observed in the field, and in correcting or verifying the guesses made there.

A geological map should be a geometrical construction on paper of the earth's features on the surface and below, and should show as fully as possible the shape of the surface, marked with the places of the observed rocks, and should give the position of the rocks or of some of the chief beds of rock below the surface as well as on it; and should be accompanied by a section, to show the thickness and sequence of the rock-beds, as well as by a cross-section of the region, to show the dips and basins of the rocks.

The relative position of points on the ground is found, of course, by the measurement of horizontal distances and angles; the height of points is found by levelling, that is, the measurement of vertical distances. The points of reference on the surface are well enough mapped by any of the ordinary methods, but the shape of the surface is far better shown by contour lines (or lines of equal height) than by hachures (lines of great steepness) or shading (dark according to the steepness). Where the map is on a large scale, the contour lines may be ten feet apart in level, or even less, and show many details. But even in maps of large regions on a small scale, contour lines, although 100, or as much as 250 feet apart in level, or even more, so that many details must be left out, still give very much more information than hachures or shading, and show, roughly at least, the height of mountains, besides their course and steepness; and on comparatively level ground, where hachures and shading have nothing whatever to say, contour lines show not only the height, but the direction of the slopes and their steepness.

Shading aims only to show the steepness of the ground, and at the very best can do this only very roughly indeed. Hachures aim to show the steepness and its direction; but can show the steepness no better than shading, and to show well even the direction of greatest steepness, would often need far greater delicacy of touch and of eye than either is capable of. Neither shading nor hachures give even a rough idea of the relative height of the ground at different points. Contour lines, on the other hand, show with more or less exactness the height of every point on the surface, besides giving with great nicety both the direction of greatest steepness and its amount. There is, indeed, no comparison between the merits of contour lines and those of either of the other two methods; and the only plausible explanation of the fact that contour lines are comparatively so seldom used is, that they are definite in their statements, they exact for their preparation a more definite knowledge of the shape of the ground, or at least a clearer idea of it, and consequently greater labor. Shading and hachures furnish a vague language that is fitted for expressing with ease vague infor-

mation; what contour lines tell, they tell with precision. If the information at hand be imperfect, contour lines will still express with clearness the best opinion or guess that can be given by the mapmaker, whose guess even may be of great value to those who have not had his means of forming an opinion. The uncertainty of the information should at the same time be shown by the wording of the title of the map, or by a note upon it, or by dotting the contour lines. Indeed, any desired degree of vagueness can be given by leaving the distance apart of the contour lines indefinite, or only more or less approximately uniform. The advantage of contour lines over hachuring has been well insisted on in Lesley's "Manual of Coal and its Topography," 1856, but cannot be urged too often, until it is generally acknowledged and they come into common use.

It is very easy to give the appearance of relief to the map by thickening the contour lines, on one side of the hills, and by altogether leaving out half of them on the other side, so that the hills may look as if they were lighted by the sun on one side, and in the shade on the other. But some confusion might arise in reading the map, because this very effect of dark shade is also given by the mere closeness of the contour lines which marks steepness of the ground. A dark shaded part may seem steeper than it really is, and a really steep place on the sunny side of a hill may, from the omission of half the contour lines, seem only half as steep as it is. It is, perhaps, better to give the relief effect by mere shading; heavy shading on one side of the hills, and light shading, or none at all, on the other side, leaving the contour lines of uniform thickness, to show the steepness of the ground by their closeness. Confusion would especially be guarded against by making the contour lines of a different color from the shading.

As contour lines give the best means of showing on paper the shape of the surface of the ground, so they give likewise the best means of showing on paper the shape of the surface of a bed of rock. It is seldom that the surface of a bed of rock is laid bare for any great distance by nature, so that it can be mapped like the surface of the ground; but it often happens that this can be done in mines. In other cases it is necessary to map the bed and draw its contour lines with more or less certainty from the exposures that happen to be visible. Not only may the actual exposures of the bed itself be regarded, but as the beds above and below are more or less exactly parallel, its position can be reckoned from an observation of theirs. At each point of observation the strike and dip of the rocks must be taken as well as their level, just as in making observations for mapping the surface of the ground; besides taking the level of a point, the contour lines near it are at least sketched; that is, the direction of a level line, and the steepness at right angles with it, are more or less exactly taken. If such observations on the rocks are made at points enough, a perfect geometrical representation of any bed of rock can be made. Even if the observations are too few for that, they may yet be enough to form a reasonable conjecture as to the position of the bed, with more or less certainty. The very putting down on paper with precision, in proper relation, what is known of the position of the rocks, aids immensely in completing a geometrical construction of them, and gives a vast deal of information beyond what can be guessed at in the field. The eye takes in readily such mapped observations, and sees their bearing upon each other, when the biggest head, with the same facts, but without a map, would be at fault, and merely muddled.

The known or conjectured shape of the surface of the bed can be shown on paper better by contour lines than in any other way, and is generally so much more regular than the shape of the surface of the ground that the contour lines of one will not be mistaken for those of the other, even if they be drawn in the same color on the same sheet; and sometimes even several different beds may be drawn without confusion. The points where the contour lines of the bed meet the same contour lines of the surface, show the position of the outcrop of the bed, one of the most important features to map, whether for practical or for theoretical purposes. It is, in fact, the geometrical construction itself, that commonly shows the position of the outcrop through most of its length, very often where it would not otherwise be suspected.

If the dips are very steep it will often not be well to make the contour lines of a rock-bed (the underground contour lines) as near together in level as those of the surface; they may be a hundred feet apart in level instead of ten, and yet show perfectly well

the shape of the bed. Sometimes it is shown very well merely by the outcrop and a single contour line, that, for example, of the drainage level of the region, or the course that a drift for drainage would take on the bed in question. With surface contour lines and underground contour lines, the depth of the bed below the surface at any point can readily be known; and this is highly important in sinking a shaft or reckoning the yield of a bed above a given level.

With such a complete geometrical representation of the shape of a bed as contour lines would give, it is only needful to make a full section of all the beds with their thickness to show the position of every bed of rock at every point. The thickness of each bed in its order must be measured, of course, at right angles with its surface; and a drawing of the whole series made to show them all on the same scale. It is plain that the whole series need not be measured at one point, but the different parts can be taken wherever exposed. The geometrical construction of the map will help very much to show their relation, and the gaps between them, if any.

Having the surface of the ground and that of one or more rock-beds shown by contour lines, and a section of all the rock-beds with their thickness, it is easy to draw a cross-section of the country in any direction, so as to show the profile outline of the ground and of each bed. Such a section across the average strike of the rocks or across the axes of their basins and saddles is especially useful; the next most useful section is commonly one along the axis of a basin. Of course the vertical and horizontal scale of such a section must be the same, otherwise the rock structure, the chief object of the section, would b greatly distorted. In making an undistorted cross-section before the underground contours are drawn, facts often come to light that would otherwise be unknown, such as the identification of beds exposed only at distant points, and the steepness of the dip at points where there is no exposure. Sections of this kind are, therefore, often a very great help in making the map itself.

Such maps and sections, then, show completely all that is known (or conjectured) of the geometrical facts of the beds of rock, the thickness, extent, position, and present shape of each bed, its position with reference to each of the other beds; the shape, size, and position of the basins and saddles, what part of each bed still remains underground, and what part has been worn away to form valleys, what part is above the lowest drainage level of the region or any other given level, and what below it; and the very process of making the maps and sections is a very valuable aid to gaining such knowledge, and often teaches as much as could be learned by very costly digging or mining. These facts are not only of the highest importance themselves, but they lie at the base of very much (if not most) reasoning toward the explanation of the purely physical and chemical facts of rock-beds.

Simple and clear as all this seems, yet it was so long overlooked and is still so much disregarded, that maps showing with the least completeness the geometrical facts of the surface and of the rock-beds were never seen thirty-five years ago, and are extremely rare even now. Pennsylvania, in fact, can claim for itself or for its citizens the credit of doing nearly all that has been done for the progress of this branch of geology, whose early history (in America at least) is but part of that of the Pennsylvania State Geological Survey, and whose later history is found in the geological work of the chief topographer of the survey, Professor J. P. Lesley, followed by that of others who have learned more or less directly from him. To him alone, in fact, belongs the credit of almost all the advances that have been made in this line of work, as well as of having first established its most essential principles. Some of its earlier hitherto unpublished annals, learned by inquiry of him, deserve to be recorded before it is too late.

The Pennsylvania Survey, under Professor H. D. Rogers, began in the year 1836, and soon discovered a very intimate relation between the surface features and the structure of the rock-beds below, a relation that is perhaps more striking in this State and Virginia than in most countries.

Early in the spring of 1839, one of the assistants of the survey, James D. Whipley, finished in lead-pencil at the end of two years' work, all his own, the first topographical map. It embraced all the anthracite region except the Wyoming Valley.

In 1840 Alexander McKinley finished a sketch map of the Wyoming Basin.

Between the spring of 1839 and the fall of 1840, Andrew A. Henderson (now Surgeon in the United States Navy) made a beautiful map of the Juniata region, partly

copied into Lesley's "Manual of Coal and its Topography" (page 137). At the same time the country north of that was also mapped by McKinley.

In 1839 J. P. Lesley, who had just joined the survey, made in Whelpley's style a map of the country south of the anthracite region and north of the North (or Kittatinny) Mountains.

In 1840 and 1841, Lesley was occupied in completing Whelpley and McKinley's maps by putting in the surrounding country.

At the end of 1841 all the materials of the whole State where any mapping had been done went into Lesley's hands, and in 1841 and 1842 he made up the State map and its cross-sections.

In all these maps no contour lines were used, but great attention was paid to elevation for the cross-sections, and the maps were made with the sections before the eye as a guide in making the hachures, and Dr. Henderson was especially successful in this.

In the winter of 1846 and 1847, Lesley made a second copy of the State map and of all the sections across the State.

In 1851 he made a great map of the Shamokin anthracite region for Mr. Rogers, a private undertaking. The country was cross-barred with section-lines staked at short intervals; and the map was made with hachures on a peculiar system of Lesley's invention, equivalent to contour lines.

In 1852 Lesley spent the summer in the field in making (for the State survey again) a great sheet of the Pottsville anthracite region. The country above ground was cross-barred with lines three-quarters of a mile apart, and the outcrops were run by parties under charge of John Sheafer; while underground surveys were also made by parties under P. W. Sheafer, and Lesley did the mapping. Contours were drawn only to determine the depth of the hachures, which were all short, showing the slopes, with eight or ten systems on a single mountain-side. The outcrops in the gaps were marked by a peculiar system of hachures that showed the dip. Every outcrop of every coal-bed and every rock outcrop were laid down. The map was between twenty and thirty feet long, and has gone out of sight, but no doubt still exists among the papers left by Rogersat his death, since the State law made all the materials of the survey his private property.

At the end of 1852 it was finished only from near Donaldson and Tremont to within six or seven miles of Tamaqua, and embraced the Mine Hill basin and the plateau of the Broad Mountain. It was intended to carry forward and finish the map the next year; but the corps was broken up; and in 1853 A. A. Dalson, with one assistant, was employed to extend the sheets. Without parties he could not do it in the same way, and Rogers had him make out of all the materials extant the reduced copy of the map of the anthracite region (with hachures), published in the State Report under Lesley's and Dalson's names; but Lesley never saw it until it had been printed. It should be called Dalson's map, as the preface to the report does call it.

This and the great map of the State with its cross-sections, are all that was ever published of all this work.

The first countouring for geological maps was done in 1853 and 1854, in a great map of Lesley's for the Pennsylvania Railroad Company, of the country from Johnstown to Greensburg, in Western Pennsylvania, covering parts of Westmoreland, Fayette, and Indiana Counties. It was eight feet long and four feet wide, and was covered with fine contour lines twenty feet apart in level, and with intermediate ten-foot lines for relief, and shading on the southeast side of the hills. I myself saw this map about 1856 or 1857, and can bear witness that it was a very wonder of topographical labor and skill. It would seem years ago to have disappeared from existence, but it is incredible that so valuable a piece of work should be destroyed.

In 1855 and 1856 Lesley mapped Broad Top Mountains with contour lines; and the survey was so minute that there were over eleven thousand stations levelled. None of this has ever been published, and it would be an extremely valuable contribution to another State survey.

In 1856 he published his "Manual of Coal and its Topography," in which he set forth most admirably the relations of topography to geology, and make public the principles of the art to which he himself had first given form. The book contains many beautiful little topographical maps and sketches by way of illustration. From that time to the present (owing partly to the increased ease of reproducing maps by the help of photography, and photolithography), he has published many specimens of his work,

especially in the Proceedings and Transactions of the American Philosophical Society, as well as in the pamphlets of private owners of mineral lands; and much remains unpublished. The maps cover many points in the Appalachian region from Cape Breton to Georgia, but particularly in Pennsylvania, and are sometimes in contour lines, with or without shading in addition, sometimes only in shading. The position of beds (say of coal or iron), is shown on them by laying down their outcrop and the course of a level upon the bed, for example the lowest water-level of the tract or region. The maps are sometimes colored and sometimes not. They show not only very great topographical and geological knowledge and experience, but high artistic taste and skill.

In 1866 and 1867, the feasibility of using underground contour lines, to give the shape of rock-beds (sometimes of three or four above one another), was proved on some Southwestern Virginia coal, iron, and lead maps of my own; a photograph of one of which was shown to the meeting of the American Association for the Advancement of Science, in 1867, at Burlington. A number of such maps have been made since that, but the only printed ones are in my "Report on the Punjab Oil Lands, Lahore," 1870. They were all drawn with special reference to the requirements of photography.

In the last three years, and especially within the last year, contour lines have come a little more generally into use for geological purposes, no doubt solely through Lesley's example and teaching. R. P. Rothwell, J. W. Harden, S. F. Emmons, A. Hague, T. B. Brooks, J. F. Blandy, and perhaps others, have published good works of this kind; not all of them, however, marking the position of the beds of rock even by an outcrop line, still less by a level.

SEWAGE FARMS.

"The Engineer."

It is frequently assumed that a principle must be unsound because its application to practice cannot be rendered remunerative. People neglect to inquire into the nature and condition of the practice, but at once lay the blame on the principle, and attribute to the cause what in reality belongs to the effect. Such a course is in many instances the easiest mode of getting rid of a difficulty. Too rigid an inquiry into the details of the practical execution of a project might, and frequently would, demonstrate that the failure in a pecuniary sense was due, not to any defect inherent in the scheme itself, but to the blunders and incompetency of those engaged in carrying it out. Unluckily, the evil effect of practical failures of this character, more especially with regard to projects of a comparatively new and untried description, is not confined to individual instances, nor to the immediate locality where they occur. The whole affair gets a bad name. A stop is put to further trials and experiments which would have been undertaken but for the prediction of financial failure; a prediction which, with respect to the subject of our article, is based upon no other grounds than the want of success which, in a pecuniary sense, has attended some examples of the use of sewage, under conditions in which no other result could have been expected. While the progress of sewage irrigation has thus been retarded, one benefit has resulted. The illusory nature of the thousand and one patents and methods for deodorizing, purifying, and utilizing sewage by any means save that of irrigation, has been thoroughly demonstrated. Local boards and sanitary authorities are now completely convinced of the soundness of the principle of sewage irrigation. The question is: Can it be made to pay? This question we shall now consider. The principle of sewage irrigation, which in its full scope includes the establishment and maintenance of sewage farms, has long ago been acknowledged to be sound, even by its enemies. It accomplishes at one operation the double duty of fertilizing the soil and purifying the effluent water. In fact, the one result is consequent upon the other. The fertilization of the soil signifies nothing more nor less than the abstraction from the sewage of those very ingredients which render an effluent water in which they may happen to remain noxious and impure, and totally unfit to be

permitted to flow into any river or natural watercourse. If it be granted that the utilization of sewage is synonymous with its application in some form or another to the land, it is obvious that the simpler and the readier the method by which that application is effected the better. Of all methods, that of irrigation is unquestionably the simplest and easiest. It applies the sewage to the soil in the manner most congenial to it, and most favorable to the development of that wonderful power of assimilation with which plants of every description are endowed. If, as is universally acknowledged, irrigation *per se*, without any regard to the fertilizing qualities of the liquid, be of very great advantage to land, the benefit must be very materially enhanced when the liquid in addition is possessed of a high manurial value. In this case no previous preparation, no chemical fortifying, no adventitious strength is imparted to the manure. It acts solely by its own specific virtue, and requires but the land necessary for its application. This desideratum brings us at once to the pecuniary question, of which it constitutes the most important element. Sewage farms have proved remunerative, do prove remunerative, and under certain fair and reasonable conditions will prove remunerative. That all have not done so there is no doubt, but an inquiry into the cause will speedily demonstrate that no other result, taking the circumstances into consideration, could have ensued.

An example in point will probably best corroborate our views. Some years ago sewage irrigation was carried on, by a company, over a tolerably large area of land, some three or four hundred acres, not very far from London. The rent was moderate, the farm was well managed and well cared for, and at the end of three successively favorable seasons the company were enabled to pay a dividend of over ten per cent. Now for the sequel. No sooner did the head landlords or owners of the land—who in this instance constituted a corporate authority directly interested in the benefit which the sewage farm, as a great sanitary measure, conferred upon their town—hear of the manner in which the farm was paying than they took the first opportunity of putting an effectual stop to profits. They just doubled the rent. At this juncture also several successive very wet seasons intervened. A change by no means to the advantage of the company was made in the management, arrears began to accumulate, and at the present time this sewage farm is paying little or no dividend, and never will until the land can be had at the originally reasonable rate. It is a serious error, and one calculated to very much retard the progress of sewage irrigation, to imagine that a sewage farm can pay a higher average rent than one farmed in the ordinary manner. On the contrary, unless with a large amount of good luck, it will not afford a high rent. The influence of a wet season is felt with much greater severity on a sewage farm than on any other. Unless in a place of so exceptional a character as Barking, the sewage must be taken regularly and applied to the land wet or dry. If the rain should turn the fields into an absolute swamp, still the sewage must go over them, or some of them. The outlay required to bring a sewage farm into a proper condition suitable for the reception of the sewage, and capable of benefiting by its application, is a heavy and a serious item in the expenditure. The maintenance also is of a more expensive character than in the case of ordinary farms. It is of a more scientific nature, and demands a far higher amount of skill and knowledge on the part of those who have the management of the affair. If, with all these drawbacks, a heavy rent for the land be incurred as well, it is too much to expect that a sewage farm will pay.

There is another consideration which very materially affects this question. It is the price paid for the sewage, which in some instances has been excessive, and totally disproportionate to its actual manurial value. The strength of sewage varies very considerably, depending among other conditions upon the water supply, the description of town whence it is derived, and the system of sewerage and drainage adopted in each particular case. The truth is that both landowners and sewage owners, the latter of whom are generally local boards, expect to make a large profit out of a project which, although it has given undoubted evidence of possible success, is yet to a great degree experimental and under trial. While sewage farms have been in cultivation for some years, and a certain amount of valuable information and experience has accrued from them, yet the

principle has not become popularized. It is not too much to assert that not one farmer in a thousand would know how to manage a sewage farm as it ought to be. Some have tried it and failed, but failures of this description cannot be set down against the soundness of the principle, nor the conclusion deduced from them that sewage farms will not pay. Independently of the question of competency on the part of those engaged in the management of a sewage farm, that of proprietorship is an important consideration. It is said, "Every Englishman thinks he can farm." It is unnecessary to comment upon the number who have, to their cost, personally found this to be a delusion with regard to ordinary farming. The idea will be found equally delusive with respect to sewage farming, Local boards as a rule are, and always will be, found to be unsuccessful sewage farmers. The most successful farmer is the man who has a direct interest in the land and the produce, and gives personal and unremitting attention to them. There is very little doubt that the cause of some of the irrigation failures may be traced, not only to the incompetency of the so-called sewage farmers, but to the notion that the sewage would do everything itself. It was regarded by some as a miraculous fertilizer; it was only necessary to apply it to the land, and it would do its own farming. But the fact is, that any one who expects to manage a sewage farm with profit must have an intimate knowledge of all the details of ordinary farming operations. He must be a thorough farmer in every sense of the term, with the addition of the knowledge and skill requisite for the particular service he is engaged in. Playing at farming is a very losing game indeed, although people are loth to admit it.

The subject of markets is one intimately connected with the success of a sewage farm. Unless there are means available for disposing promptly and regularly of the produce at a fair price, the farm will not pay. So far as the grass is concerned, that can always be sold, and also most profitably, on the land itself; but the root and other crops for the most part must be sent to market. Here a good deal of practical knowledge is necessary, both with regard to the selection of crops and the time at which to send them. Tons upon tons of root crops which have been cut at the wrong time and sent to market, only to find it overstocked, have been sold for a mere trifle. We can call to mind one case, in which a large supply of red cabbage was dispatched to a market in which there was a glut of that vegetable, while there was not a single green one to be had. A knowledge of this fact at the farm would have made a considerable difference in the pecuniary results of that day's consignment. While the points to which we have referred in our present article prove beyond doubt that sewage farming requires no ordinary amount of skill, technical knowledge, and practical ability, to make it prove remunerative, yet we see no valid reason why it should not pay, provided certain conditions, which are indispensable, obtain. The rent must be moderate, the price paid for the sewage low, and under some circumstances none at all, and moreover the matter must be regarded by all parties in a proper light. In other words, the utilization of sewage by its application to land must be considered as a great sanitary utilitarian measure, and not as a speculative project which is to pay enormous dividends and enrich everyone connected with it. This it will never do, but, on the other hand, sewage farms, under proper treatment, will return a safe and fair percentage for all capital expended upon them.

THE MANUFACTURE OF IRON AND STEEL RAILS.

By JOHN B PEARSE, Superintendent of Pennsylvania Steel Works.

Transactions of the American Institute of Mining Engineers.

In order to get an idea as to the strength of steel rails, it will be well to review the tests to which iron rails have been subjected. In England, Mr. Ashcroft found that the best 80 lb. rails broke under a 300 lb. weight, falling 15 feet. In Germany the Society of Railway Managers determined on and have long applied a test of 1,000 lbs. falling 10½ feet, as the standard which all first-class iron rails must reach. In this country no inspection nor test is applied, but tests made

show that iron rails from our most reliable makers, break under a six foot fall of a 1500 lb. drop as an extreme test, most of those tested breaking under a far less test; some breaking with less than a three foot fall of the same weight.

Everywhere where steel has been used, engineers have come to the conclusion that some test is required to show the regularity and strength of the product. As compared with iron, the tests which steel will stand are wonderful. After numerous experiments partially based on the experience of the rail-mill at Graz, belonging to the Southern Railway of Austria, the Society of German Railway Managers fixed upon a test of 2,000 lbs. falling 13½ feet. They found that this test represented the steel which suited their necessities, and also found that with steel of otherwise average purity, this test represented about one-half per cent. of carbon, and made it a rule to take no steel containing under three-tenths of a per cent. of carbon, because it was too soft. They expressed a hope that a harder steel could soon be made tough enough to stand the same test. In England, a test was adopted of 2,240 lbs., falling 15 to 17 feet on the rail on heavy bearings. This test has been found satisfactory under heavy traffic on average road-beds, and has been invariably retained by English makers, and adopted by American makers. It is an expeditious practical way of ascertaining the qualities of the rail. Experiment in Germany and experience in England pointed out the test corresponding to the proper grade of steel, and the test adopted has been considered the most practical one. The jar from a moderate weight (2,240 pounds), falling from a great height, is more sudden than that imparted by a heavy weight falling a small distance, and better adapted to exhibit the toughness of the rail. This latter is the object had in view in all tests, as it would take far too long a time to determine the quality of rails by a treatment approximately similar to that received in the track. An objection of some force has been urged against the English method of obtaining test pieces. They take one rail from each day's rolling, to indicate the quality of the rest. In this way their test becomes a matter of chance, and nothing they have yet done removed this character. Our American practice has been to test every charge, thereby insuring beyond doubt the quality of the rails.

After a short experience with steel rails it was found that their homogeneity is their distinguishing characteristic; but they unite entire homogeneity with considerable hardness as compared with iron. There are no layers to peel off, no welds to open out, the ends of the rails do not broom out as iron rails do, and the head wears uniformly along its whole length. Not only is the single rail entirely homogeneous, but all the rails made from a single charge have exactly the same qualities. Many experiments on the steel at Seraing, in Belgium, in Austria, and in this country, before and after its conversion into rails, show this to be a fact.

But the hardness is a most important point as regards wear. Some first-rate English rails have been found too soft for roads with heavy traffic. Therefore, a rail is wanted which will be hard enough to stand abrasion and wear, but strong enough to stand all the strains to which it is liable. The railroad engineer's idea of hardness is that quality which imparts durability without brittleness. Hardness is sometimes erroneously associated with brittleness because some hard bodies are brittle, but in steel brittleness arises from causes entirely different from those which produce hardness. The steelmaker's idea of hardness is a composite one—one that results from considering the effects of physical structure or grain of the steel, and the effects of carbon, phosphorus, and manganese. The effects produced by the presence of these elements far exceed any brought about by change of physical structure. Phosphorus and manganese occasion brittleness, while carbon in excess is seldom present, as the processes through which the rail passes have a constant tendency to reduce it. The state in which carbon is present in the rail is, however, remarkably influenced by mechanical treatment and the resulting physical structure. Those modes of reduction which work quickly and forcibly exert a strong influence to retain the carbon in a combined state, while the slower methods, on the contrary, permit some of the carbon to separate as graphite. These facts have been observed by Gruner and Caron, and have been corroborated in Austrian practice, as the following analyses of steel will show:

(*a*) Steel made for heads of steel rails at

Graz, and rolled into shape without hammering:

Combined carbon	03.8
Graphite	0.65
Silicium	0.05
Manganese	0.07
Sulphur	0.05
Copper	0.08
Iron	98.57
	99.85

(*b*) Steel made at Neuberg and hammered into shape:

Combined carbon	0.234
Graphite	none
Silicium	0.033
Phosphorus	0.044
Sulphur	traces
Manganese	0.139
Copper	0.105
Iron	99.445
	100.

Both these steels were soft Bessemer steel, and from observation I made at the two works on the respective quality of their metal, I see no reason to doubt their correctness. A remarkable point in the matter is that the iron at Neuberg was much more graphitic than that used at Graz. At Neuberg they tapped direct from the blast furnace, and their "blows" averaged about thirty minutes, some running up to fifty minutes. At Graz they remelted their iron in an air furnace, and their "blows" were much shorter. The iron each works used was then of substantially the same character, made by charcoal from spathic ore. Neuberg made its own iron, while Graz bought its own iron largely from Mariazell and Eisenerz, furnaces not far from Neuberg.

Now, at the Pennsylvania Steel-Works, we have a quite graphitic mixture for conversion, but we find scarcely any graphite at all in the rails—in fact none. Out of many tests we have only one, an apparently abnormal one, in which the graphite amounted to 0.08 per cent., it being generally present in too small quantities to be estimated.

Speaking within the limits of steel manufacture, it is safe to say that brittleness has nothing to do with the mechanical treatment, yet by this treatment the state of the carbon may be controlled and the specific gravity and consequent density of the steel increased. Rails are brittle when too cold-short from the presence of phosphorus and manganese. The proper proportion of the former forms the most delicate point in steel-making, and must always be kept within safe limits. No good steel rail has ever yet been made with more than one-fifth of one per cent. of phosphorus, and half that is considered too much by Bessemer. In regard to manganese, our experience is not yet fully ripe. Its action, however, is far less dangerous than that of phosphorus, and in small quantities is beneficial.

We have thus a definite idea of the important qualities of steel rails and the proper tests to show their uniformity. The tests made on the steel preclude possibility of brittle steel being used, and it is evident that those methods of reduction which unite the greatest hardness with the necessary strength are to be preferred. In general terms, a steel rail is wanted to last a lifetime, and to be strong enough to stand all accidents of wear.

Railmaking begins with the Bessemer ingot. This is a block of highly crystalline metal, the tensile strength of which is low, and which contains some blow-holes or bubbles formed by the carbonic oxide retained by the liquid steel. The inner surface of these bubbles is generally oxidized, and they are apt to be more numerous near the surface of the ingot.

The first steel rails made ten years ago were treated like cast-steel. Until 1863 they were made from ingots seven to eight inches square and four and a half feet long in four heats. In the first two heats the ingot was hammered down to size, one end at a time, and swaged in dies to the shape of the first pass of the rolls. Then the bloom, by this time eight feet long, was rolled in two heats through twelve passes into a finished rail.

This process was excessively crude, wasting everything a steel-maker cares to save, and as the rails were found deficient and their weak points tested, it was found that the small size of the ingots and the little work done on them caused a great number of imperfect rails and a very poor quality in the steel. At this time the expressions of want of confidence in Bessemer steel took shape. We have now, however, surmounted all difficulties, and produced a reliable uniform quality of steel in enormous quantities considered in the

light of former capabilities of production. We now use very large ingots, which necessitate thrice the work formerly applied. In 1867 the ingots were raised in England to ten inches square, and in 1870 to twelve inches square, which is the size in general use. In America we have had exactly the English experience with small ingots, the efforts to use them to advantage having entirely failed.

Seeing, then, that large ingots weighing three-quarters of a ton, and making two rails, have been found necessary, it has become a question as to what mode of working them up gives the best results. I think that hammering furnishes the preferable product, and my present experience goes to justify the opinion. Rolling is preferred by some makers because it is thought cheaper, but I think the better wear of a hammered rail is a strong point in its favor. Rolled rails are generally softer than hammered rails, for the reason I have given, namely, because their carbon is apt to be partially separated as graphite, and their density is less.

There have been, in the history of iron metallurgy, two noted contests between rolling and hammering, in one of which the hammer came off victorious, in the other the rolls. I refer to the manufacture of hammered iron and to that of armor plates. Hammered iron is a necessity for smith work, and the qualities imparted to it by continued piling and hammering are wonderful as compared with ordinary iron. The reputation of the Low-Moor and Yorkshire iron tires and plates is world-wide, and the steel tyre had in the Low-Moor tire for some time a formidable competitor. In this case the benefits are produced by a better texture of the iron and greater ductility developed by the work done. The cinder is thoroughly expelled in the blooming and first piling, and may be left out of the question. In the other case the object was to get as soft and wax-like an armor plate as was consistent with the strength necessary to resist the impact of the shot. As the work done by the shot generally used represents in foot-pounds the effect of one (gross) ton falling a mile and a half, it will readily be acknowledged that there is little similarity between the case of an armor plate and a steel rail, which has to stand a ton weight falling only 17 feet.

In my own experiments on the effects of the two processes, I compared ingots of the same steel with an average area of respectively about 75 and 110 square inches, average section, as they were the only moulds I had at the time to compare. I found that the rails made of blooms, hammered from the ingots of the latter section, stood over 100 per cent. more than the rails made direct from the ingot. The bloom was hammered to the size of the ingot, and each rolled in two heats, one of them a wash heat, into the same kind of rails. I tested in this way 31 different charges. Weight used was 2,000 lbs., bearings two feet apart. The rails from ingots stood 21½ feet fall of this weight, showing $1\frac{6}{10}$ of an inch deflection without breaking. The rails from the blooms stood a 43 foot fall of the same weight without breaking, and showed a deflection of $3\frac{9}{10}$ inches. This leaves a surplus of 50 per cent. in favor of the hammered rail, deducting 50 per cent. for amount due to difference of area of ingots. To show the connection, on a manufacturing scale, of these tests with the actual result, I would remark that we made 13,285 rails out of the ingots of 75 square inches average area. Of these there were rejected by the railroad, for insufficient strength after delivery, 178 rails, or 1⅓ per cent. Of the larger ingots we had made up to the fall of 1870, 34,320 rails, and had rejected for all causes, after delivery, only 18 rails, or $\frac{1}{2}\frac{1}{0}$ of one per cent., or a quantity only $\frac{1}{1}\frac{1}{6}$ as large as before.

We, therefore, continued to hammer, but now use an average section of 150 square inches; doing two-thirds the work under the hammer, and only one-third in the rolls. Our rails thus produced stand a ton weight falling 17½ feet, and leave an ample margin of reserved strength. We have had recent tests, in which the rail stood what was equivalent to a ton weight falling 70 feet without breaking, but have not yet got up to the armor-plate standard of a mile and a half. Out of a lot of 1,200 tons of 58 and 60 lb. rails, not a single rail, out of the 439 tests given, broke under a ton weight falling 16½ feet. We have since had many similar series.

The bubbles in the ingots give some trouble in the subsequent working, sometimes occasioning cracks in the ingot requiring to be chipped out. This we do, as we hammer the ingot down, without hindering the hammer in its work. Rolls are apt to laminate these bubbles instead of forcibly compressing them like the hammer, and it

sometimes happens that the bubble breaks out on the surface of the bloom, and causes a long streak where the metal is not sound. These streaks are especially noticeable in the head of the rail. In order to obviate the cracks resulting from these blowholes, a hammer must be associated with the rolls to chip out bad places; and this renders the rolling process more complicated than it would appear at first sight. I do not see why it is not simpler to do all the work under one tool, namely, the hammer.

The objections to hammering, on the score of cutting sharply into the metal, are not, in my opinion, of weight, as our experience agrees with the English, that you can hardly have too heavy a hammer for steel. We can strike two full blows of a 12-ton hammer on the same place without deforming or injuring the bloom in any way, or making a mark on it deeper than $\frac{3}{8}$ inch each time. As showing what steel will stand, I will say that I have seen, in Vienna, Haswell's hydraulic press reducing ingots from 10 inches thick to two inches at one squeeze, without injuring the steel, which was from Neuberg. It is thus surely idle to talk of a hammer as injuring steel in any way. The stroke of a heavy hammer works uniformly through the bloom, drawing the interior as much as the surface. We want to make a hard and tenacious bloom, and the concentrated blow of a heavy hammer is well adapted to that end. We lose practically nothing in ductility as compared with the rolls, and have ample room within the limits of our strength. The chemical composition controls the brittleness of our rails, and as long as we keep that right, we can make a comparatively hard rail well adapted to wear.

In regard to the amount produced by the two methods in the same time, the hammer compares very favorably with the rolls. A blooming-mill turns out about 55 tons of blooms a day from ingots. We do as much as that daily under a 12-ton hammer, and have done much more than that for a considerable time, so that the relative capacity of the two is hardly decided as yet. In five to six minutes we can hammer down, chip, and cut in two, and carry away, a large ingot, reducing it to one-third its former size; and in thirty-five to forty minutes do the whole work of getting a heat of five ingots hammered complete into finished rail-blooms, requiring no subsequent hand-chipping. For three months this hammer did an average of about 70 tons of rail-blooms per day, turning them out sound and well chipped.

As a matter of interest, it may be well to refer to the fact, that at Neuberg, in Styria, they use a 19-ton hammer on steel, and according to published statements, produce under it in a week only 65 tons out of two furnaces in $11\frac{1}{3}$ turns. They hope, by using four furnaces, to get up to 130 tons a week. It shows well the spirit of American work to compare our product with this. We do now over three times as much as they hope to do, and do it under a hammer of under two-thirds the weight. The weight of ingots is about the same.

I have explained above my reasons for preferring hammered rails, all derived from experience capable of easy verification. In practice we have found, as far as we could compare hammered with rolled rails, that the former stand the treatment they have to suffer better than the rolled rails. From experience with rails of different making, rolled and hammered from ingots of the same size, I am enabled to say that the hammered ones have far less rejections on all accounts than the rolled ones, and that their strength against sudden jar is greater.

I believe, therefore, that the hammered rails are superior to the rolled in very important characteristics. I do not deny that rolling may be improved so as to equal a hammered rail. That is not impossible, nor improbable. It has not done it yet, in my opinion, but when it does, I shall be most happy to change my opinion.

In order to show the relative endurance of iron and steel rails, I would like to mention a case that may be regarded as furnishing an American experience of steel rails, equalling that had on the English railroads, and especially on the London and Northwestern. The Philadelphia, Wilmington, and Baltimore Railroad laid, in their yard in Philadelphia, steel rails on one side of the track, and iron rails on the other. The steel rails were hammered rails, and were, with the iron, laid in 1864. The steel rails wore out some 17 sets of the iron rails, and then the company stopped the experiment, laying steel on both sides.

On a curve of 525 feet radius, steel

rails have lasted intact since 1865, and are as perfect as when laid, where iron rails had before lasted only from three to six months.

None of the rails of the Pennsylvania Steel Company, nor of any other company in this country, have ever been worn out by traffic or shifting work, so that, after a five years' experience of American makes, I have reason to believe they will last at least a generation, under the hardest service.

DIRECT PROCESSES.

By CHARLES M. DUPUY, C. E.

The great wealth of magnetic ores in this country is exceptional throughout the world. While they are of surpassing richness—almost pure iron—we work them into metal at a high cost for labor, and at a great waste of fuel and ore.

It is curious to note the slow development of any art, more particularly the manufacture of iron, surrounded as it is with so many real difficulties, and hedged about by so many firmly rooted prejudices.

Iron ore is mainly a compound of oxygen gas, earthy matter, and metallic iron. Almost the whole theory of reduction of rich ores is to volatilize oxygen, for the earthy matter may be nearly all washed out before heat is applied. Oxygen is the arch-enemy. In well-washed magnetic ore as usually prepared for the forge fires, nearly one-third, by weight, is oxygen, and the entire remaining two-thirds is metallic iron.

Carbon in its various forms, *par excellence*, is the reducing agent. At the required heat, the oxygen in the ore, having a greater affinity for the carbon, leaves the ore, and passes off as carbonic oxide. *The most perfect system of reduction consists in bringing ore, carbon, and heat together, in the most exact and economical proportions.*

The earliest process, practiced by the ancients, and still largely in use to this day, is the forge-fire, Catalan forge, or bloomery in its various forms. Here, rich ore mingled with charcoal, is subjected to a blast in a furnace, resembling a large blacksmith's forge, until reduction is effected. On the theory that oxygen will leave the ore when heated, and unite with carbon, the forge-fire method at first glance would seem to be a perfect process. This, however, is not the case. While reduction is in progress, and until the last atom of oxygen has left the ore, it is always ready to seize with avidity any "*free oxygen*" it may find in the blast, or draw from the surrounding atmosphere. It is this "*free oxygen*" which so largely consumes the fuel and is the means of melting down a large proportion of ore to a useless cinder. It causes a consumption of 300 to 500 bushels of charcoal, and over two tons of washed or separated magnetic ore to the ton of iron, whereas, less that one hundred bushels of the former, and less than a ton and a half of the latter, would be quite sufficient, could these objectionable features be removed. Another objectionable feature to the forge-fire is want of uniformity of product. That part of the bloom formed nearest the blast is semi-steel, while that farthest away is soft iron.

Fredrick Overman, in his little work on steel, says we want purer iron. "The immense ore beds of New York, New Jersey, Missouri and Wisconsin, as well as of other States, are unsurpassed in purity, and should produce iron equal to the best Swedish, and at a much cheaper rate than it can be imported. Ours are peculiar conditions, and resemble those of no other people. We should not copy the processes of other nations, but work out our own method in our own way."

The immense deposits of rich cinder from the forge fires which had been accumulating in England since the conquest by the Romans, finally suggested the invention of the blast furnace to work them up. It was soon found useful to smelt the lean ores, which abound so largely throughout Europe, and although the invention dates back three hundred years with comparatively but few improvements, the blast furnace still continues the great right hand of the iron master.

The facility of melting down large quantities of crude material, so as to separate the metal from its grosser impurities, in large and continuous operations, was certainly a great step to keep pace with the

rapidly increasing wants of an iron age. Still, while the blast-furnace frees the metal from its oxygen, and separates by specific gravity a large portion of its earthy impurity, it is by no means a perfect instrument for the manufacture of superior *wrought iron*. Owing to the variation in the atmosphere, and other uncontrollable causes, the run of a blast-furnace, from day to day, not unfrequently is wanting in uniformity, and, besides, is always charged and intimately incorporated with four to five per cent. of carbon. This carbon clings more tenaciously to the iron than the oxygen did to the ore, for the ore parted with its oxygen at a red heat, but pig-metal must a second time be melted, and skilfully manipulated for nearly two hours, before it gives up its carbon. It is true that the second melting, although involving high cost for fuel, labor and waste, separates quite perfectly the earthy impurities which may have remained; yet the fact that the forge-fire can exist, and that its product is so largely in demand at a much higher price, and for purposes that puddled iron can not supply, is conclusive proof that blast-furnaces do not fill up the need for a certain high quality of metal, which can only be produced by a direct method. The truth probably is, the blast-furnace is best adapted to working the lean, while a better direct method should be adopted for the rich ores.

The vast deposits of rich ores, yielding from 60 to 70 per cent. metallic iron, have long demanded a better system of reduction. During the past half century, various expedients have been suggested. One proposed to subject ore with carbon to heat in clay crucibles, until reduction takes place, then to empty and hammer the product, but it was found the iron adhered to and became incorporated with the crucible, causing waste of the former and destruction of the latter. Another suggested ore with carbon, heated in gas retorts. Gas retorts were tried, but were too perishable to be found useful. Another proposed heated vertical tubes, or retorts of fire-bricks; these, like the gas retorts, were too soon destroyed by a deoxidizing heat to be practical. Still another aimed to deoxidize ore with carbon, on fire-brick tables, which were heated above and below. The sensitiveness of the ore to the absorption of oxygen found floating in the furnace failed to secure a perfect deoxidization, and this plan was rejected. All these, and many other processes, although at times producing iron of superior quality, were not found economical. They have had their day of experiment and abandonment, and still a better direct method than the forge fire is demanded.

The ore seems to require a continuous reducing heat, from the time it is placed with carbon for deoxidization until it is reduced and consolidated to iron. Carbon will not act efficiently in withdrawing oxygen from the ore, if it can find "*free oxygen*" in the furnace. Such is the affinity of ore for oxygen, that however well the deoxidizing process may be progressing, if at any stage, until it is completed, the heat is changed from a "reducing" to an "oxidizing" heat, success is measurably defeated, and waste the result.

The whole aim should be to continue a reducing heat in the furnace until the ore shall be *thoroughly penetrated through by it*, at the same time to *shield both* ore and carbon by a *suitable covering from any free oxygen*, until it is not only reduced, but consolidated to metals. Whatever earthy impurity may remain in the ore after cleansing, and before the application of heat, is readily removed by the high heat required to weld the particles of reduced metal together. At this heat the earthy impurity is liquefied, and is compressed from the porous mass of iron, under the hammer, as water is squeezed from a sponge.

The elder Mushet—the father of iron experimentalists—observed the wastefulness of its manufacture, both in the forge fire and blast furnace, and spent his long and useful life in the improvement of iron. Among various other experiments, as early as 1794, he mingled ore and carbon in a crucible, and subjected it to a heat which reduced the ore and welded its particles together. At the same heat, after breaking the crucible, he was delighted to be able to hammer its contents into a solid bar of iron. Here was the real starting point of all the direct processes. The containing vessels, retorts, chambers or crucibles of various shapes and sizes, which since that time have been the subject of so many costly experiments and disappointments, must necessarily be of considerable thickness, to withstand, for a single operation, a heat sufficient to penetrate from the outside the few inches in thickness of ore and carbon lying dormant within them A heat energetic enough to produce a thorough deoxidation in a reasonable time,

practically, is too destructive and costly of crucibles to be made profitable. To prevent this damage, a moderate temperature, reaching over a longer period, has been tested, but a moderate heat only partially deoxidizes the ore; it requires a high temperature to accomplish deoxidation thoroughly, and with sufficient energy. Beside this, the newly made metal is left in a porous, spongy condition, and is peculiarly sensitive to the furnace gases. It will receive a varnish of fresh oxygen over the innumerable little surfaces of its cells or pores or fibres, not only while exposed in that condition in the furnace, but still more the moment it is cooled and penetrated by the pressure of the atmosphere, just as every bar of iron, after cooling, receives a scale of oxygen on its surface.

To prevent this attack of the atmosphere, the hot, spongy iron, without external exposure, was at once dropped into the balling or reverberatory furnace. Still the waste proved excessive. This may be satisfactorily explained. While a portion of the oxygen, thrown into the furnace, unites with the carbon to supply a welding heat, *another portion penetrates to the infinitesimal surfaces of the pores or fibres of spongy metal, and these combined surfaces, so oxidized, are of such large extent as to cause great waste.*

The aim, then, was to close these pores, so as to prevent the penetration of furnace gases, by pressing the cooled sponge into blooms with hydraulic power, previous to the second heat. If the ore could have been thoroughly deoxidized at first, by the application of sufficient heat around the crucible, and if the surfaces of the pores had not been varnished with oxygen, on exposure to the atmosphere, as explained, this step might have been successful, but the small yield and rich cinder still pointed to a defect.

We may pass by all that class of processes for working ores to metal at one operation, on a series of tables or shelves, in a reverberatory furnace. The most prominent of this class is Harvey's process, on which large sums were fruitlessly expended for a number of years. They have not been successful, because the oxygen of the furnace is quite as ready to penetrate the cells of the partially reduced and exposed ore as it is to unite with carbon to support combustion. For a like reason all furnaces, either rotating or fixed, with the flame passing through them, and coming in contact with the ore, cannot be the most effective.

For a time there was a process which was thought to promise success, because the deleterious furnace gases were excluded throughout the operation. The ore was packed with carbon, in alternate layers in a steel converting furnace, to the extent of 40 or 50 tons, and gradually heated from the outside, up to the welding point. In a couple of weeks the metal, thoroughly reduced and consolidated, was removed in a cool state to the balling furnace. The maintenance of this converting furnace up to a high heat for repeated operations would of itself have defeated this process, had there not been a more serious difficulty. The ore, it is true, was thoroughly reduced, but was more or less carbonized, up to the condition of cast iron, but the process was too expensive, for the manufacture of pig iron it could never have successfully rivalled the blast furnace.

In following out these various devices, they were thought to be fairly based for success on the exact results from covered crucible in the laboratory, and in keeping with the blast furnace and forge-fire operations. In the laboratory, the heat applied outside of the closed crucible brings all the metal either to cast or wrought iron, at pleasure, by properly proportioning the carbon, because no external oxygen can interfere. Deep down and between the thick walls of the blast furnace crucible in like manner all atmosphere is excluded, and the large excess of carbon it contains thoroughly decomposes the oxygen of the blast. In it the high heat required for perfect deoxidization is maintained, and the metal, saturated to a high degree with carbon by the powerful blast pressure, is nearly all saved as a carburet or pig iron. The shallow forge fire, with a light blast, certainly produces wrought iron in a few hours, but with great waste of fuel and ore, which is accounted for by the penetration of the atmosphere.

Experience proves that it is clearly impossible to impart sufficient heat from the outside of a chamber or crucible to accomplish practically, on a large working scale, the results reached by laboratory experiments in the chemist's crucible. Nor can a high column of ore be uniformly penetrated by a blast of reducing gases forced through the mass. As in the German "Stuck" or "Wulf's" oven, the blast

pressure necessary to penetrate to the top a high column of ore, at every operation, will produce a mixture of cast iron, steel and wrought iron, of grades varying from the base upward. A low column of ore will have the atmospheric objections of the forge fire. It is, further, impossible to maintain a welding heat in the ordinary reverberatory furnace without having the delicate fibres of partially reduced ore largely destroyed by the deleterious gases to which they will be more or less exposed.

To ensure an economical, direct method, the operation must not pause with the production of spongy iron. As in the chemist's closed crucible, or in the blast furnace or forge fire, the process must go on with a continuously increasing heat, until the cells and fibres, produced by the withdrawal of oxygen from the ore, *are compressed* together *and solidified into a cake, at the pasty condition of the metal.* It is then a commercial product of wrought iron, either hammered or otherwise.

How shall this be accomplished? Some years since the writer suggested that rich ores, mingled with the proper proportion of carbon for reduction, should be placed in thin sheet iron cases, of size most convenient to handle. Many of these canisters of ore, to the extent of several tons, placed in a simple, cheap furnace, of a peculiar device, in a few hours will become caked and solidified to wrought iron without further labor, while the encasement will be preserved to the end, the whole to be hammered into a bloom or bar at the same heat.

Deoxidization commences immediately on the introduction of the canister into the furnace, as proved by the blazing of carbonic oxide from them, which continues without intermission until reduction is completed. The heat, which is gradually absorbed, increases in intensity until reduction is effected, and the particles of iron are pasted or mated together; then canister and contents being withdrawn, are welded together in any of the ways puddle ball is usually treated.

The sheet iron canister or crucible will cost from $5 to $6 to the ton of iron produced. It is a convenient, portable package, keeping the particles of ore in close contact with the exact proportion of carbon required for reduction. It allows the heat to penetrate readily on all sides. It is homogeneous with the new metal, and welds up with it under the hammer. Above all, as it *shields and protects the ore from the blast and furnace gases during the whole operation of deoxidation and consolidation, the metal is of superior quality,* and is *nearly all saved.* A series of experiments, extending over many years, confirms the writer in the belief that this process solves the problem of the manufacture of wrought iron direct from the natural oxides, on any scale of magnitude, and at a cost, both for plant and manufacture, which will effect a great saving over the indirect method. The results of these experiments, in the form of samples of metal taken at all stages of the process, are open to the inspection of any one interested in this subject.

FURNACES AND THEIR CONSTRUCTION AND MANAGEMENT.*

By M. CHARLES FAIRBAIRN.

"The Engineer."

Within the last two or three years a great change has taken place in the conditions under which our manufacturing supremacy has been maintained, and, whether we believe the unpalatable fact or not, there is not the slightest doubt that the sudden and rapid increase in the price of materials and labor has tended to place us more in a position of equality with competitors whom we were wont to overlook and despise. The change came too suddenly upon us, and has been too sweeping and arbitrary in so short a time, inasmuch as the necessary improvements in labor-saving machinery and its introduction could not be attempted, far less completed, in substitution of manual labor and many expensive processes we have so long allowed ourselves to become habituated to. At the same time I believe that the revolution which has taken place will ultimately prove beneficial.

The change has to a great extent been secured by powerful combinations among

* Read before the Edinburgh and Leith Engineers' Society.

the industrial classes directed to one point, and whether that power has been judiciously applied is apart from our subject, except in so far as it has given a greater desire and more necessity for those improvements in machinery which at less cost and by more rapid production will inevitably reduce the prices of materials, which have been increased far beyond their normal value. In this sense the public are nearly always gainers in the course of time. It must be evident to every thinking mind that the arts and manufactures are every day becoming more intimate with and dependent on the severer sciences in a more recognized form, and that as we move onward in the career of improvement that connection becomes more and more intimate; and as the applied sciences derive their facts from experiment, and the deductions on which their utility depends belong to the province of abstract science, so in all departments of human industry and knowledge we are all mentally dependent—the chemist in his laboratory, the philosopher in his study, and the artisan at his bench, are all working towards one great end, acquiring new facts and adding to the sum of our experience.

The mutual assistance and aid rendered by this division of labor has probably stimulated the spirit of inquiry and discovery more forcibly from the unusual position in which we find ourselves placed with regard to the cost of materials and labor, because now when the pressure has come we begin to realize the truth that in many instances the fact of having an abundant and cheap supply has been the cause of apathetic indifference and reckless wastefulness. Accordingly we have failed in a great many instances to utilize our experience of the beneficial effects which improved machinery has conferred on us, in a great many of our manufactures, during the last half century; and if, as I believe, the unreasonable demands of labor have only stimulated us to more intense activity in the direction of improvement, it has accomplished more good indirectly than we are ready to admit at first sight.

Perhaps not any of the materials in use in our manufactures, and upon which our prosperity depends peculiarly, have been so much and so recklessly wasted as those great stores of fuel so providentially placed within our reach. It would almost seeem as if we were endeavoring to ascertain the truth of the fable of the goose that laid the golden egg, by killing our goose as hard as ever we can. It may or may not be true that our coal stores are being rapidly exhausted, but this much is certain, that every day brings that time nearer when our coal will be more expensive to get, and necessarily less of it; and we do not yet see our way to finding a substitute at anything like a reasonable costs. True we hear a great deal of nonsense talked about the decomposition of water supplying gas at a cheap rate, others suggest electro-dynamic engines; but so far as we know yet—and I am afraid so far as we are likely to know—there is no source of power at all approaching to coal for cheapness, and there does not appear any probability of heat engines ever being supplanted by electricity or galvanism, of which such costly material as zinc or other metals supplies the force.

Dr. Joule, in some experiments conducted some time ago, ascertained that a grain of zinc consumed in a galvanic battery generated sufficient power to raise 145.6 pounds one foot high. Now it has been proved that a grain of coal consumed by combustion exerted a power of nearly 1400 foot-pounds. This is nearly ten times the power given out by the zinc. It is said, however, that thermo-electric engines utilize the initial force supplied about four times better than heat engines, which would make a grain of zinc give about two-fifths of the power of a grain of coal. But zinc costs from forty to fifty times as much as coal, while it gives only two-fifths of the efficiency.

During a number of years I have been trying experiments with furnaces, with a view to the economy of fuel. As opportunity occurred, the furnaces I experimented on have been of various kinds, but lately they have been what are know as reverberatory furnaces, chiefly used for puddling and reheating iron. Before entering upon a description of the furnace I found to answer my purpose best, I will briefly desribe what a furnace should be, and how it should be constructed to answer all the conditions requisite for economy of fuel; and, secondly, our furnaces as at present constructed, and why they are so wasteful. The great variety of

kinds of fuel, although they contain nearly the same ingredients, but in different proportions, renders it a somewhat difficult task to define what a furnace should be. Hydrocarbons, such as pitch, tar, naphtha, and petroleum, have all to pass into the gaseous state before they can be burned.

Coke, which is coal with all the bituminous and gaseous portions taken out of it, is nearly pure carbon with a small proportion of ash.

Anthracite coal, which is very similar in its nature to coke, is almost wholly composed of free carbon. It is liable to split and fall into powder, it burns without flame, and with very little smoke, and requires a very strong draught.

Bituminous coal, again, of which there is an immense variety, has a smaller proportion of carbon with a mixture of hydrogen and oxygen. From this it will appear evident that special provision must be made for a supply of air to support combustion instead of the different kinds of fuel used. Thus, a furnace arranged for burning bituminous coal might be very wasteful in burning anthracite coal; due regard then must be paid in all cases to the character of the fuel employed. The indispensable conditions attached to a good furnace for all kinds of fuel are: [1] A good draught which can be regulated at will, so as to avoid forcing the fire too much; (2) a large and roomy combustion chamber surrounded by fire-bricks, and removed, if possible, from the place where the heat is to be used; (3) that the sides or walls of the furnace have at least two thicknesses of bricks nearest the fire, and an outer wall having an air space between of about three inches; (4) that the supply of air to the furnace can be regulated at will.

I do not think we can always command all these conditions, especially in a furnace constructed on the principle of depending on atmospheric pressure for draught; and the reason is obvious, because in order to maintain a good and equal draught we require not only a tall chimney, but the chimney must be maintained at a high temperature, about 600 deg; and as the temperature within the furnace may be assumed at 2500 deg., the abstraction of this large quantity of heat to keep the chimney at a sufficiently high temperature amounts to one-fourth of the heat, and consequently the fuel which is expended for this purpose alone. Nor is this the only drawback. The attendant on the furnace, who may, and often has other duties to perform, puts on a heavy load of coal. The flues and chimney are rapidly cooled, and the power of the draught reduced at the very time when it should be greatest. The second and third conditions mentioned may assist in getting over irregularity in the power of the draught to a certain extent—that is a large and roomy combustion chamber, and the sides constructed to prevent loss of heat. I do not suppose any person who has not had an opportunity of seeing a furnace in operation with the heat confined in the manner described could have believed the effect would be so powerful; the inner lining actually acquires a white heat, thus serving as an accumulator, which is given out again when the temperature of the fire is reduced (as in the case of a fresh charge of fuel), and at the same time assisting to bring the fresh fuel into active combustion more rapidly; the heat is again returned to the fire-bricks, and kept ready for future use.

Doctor Siemens has taken advantage of this idea, although in quite a different way, in his celebrated gas furnace; and as it has been very effective in economizing fuel in very large iron manufacturing establishments, I will try and describe it briefly here. A close furnace is constructed entirely of fire-brick, and capable of holding several tons of coal. The grate bars slope at an angle of 45 deg., so that the fuel as fast as it is consumed slides down on the top of the fire, making the furnace in a manner self-feeding. The fire is lighted from the bottom, and just enough air admitted to support a slow combustion. The small quantity of carbonic acid formed at the bars where the air gets free access is decomposed as it passes through the mass of incandescent fuel above, and tak ing up more carbon is converted into carbonic oxide. The products of combustion are carbonic oxide, hydrogen, and oxygen. These products are passed on through a pipe into a furnace, receiving on their way the requisite quantity of air, and becoming thoroughly mixed with it, are consumed in the furnace. The calorific effect of this furnace regarding the distribution of the heat developed has been investigated by Kraus, and may be condensed thus:

Amount of heat expended in the first process, 31.7 per cent. of theoretical effect of complete combustion, that is in obtaining the gases. Thus, heat lost in the chimney and in transmission from the gas-producing furnace to the gas-consuming furnace is about 23.86 per cent. leaving 76.14 per cent. to be utilized. Again, taking into account the loss—if we may call it so—of 31.7 per cent. In producing the gas, the total duty of the coal used, 52 per cent. and 48 per cent., represents the loss. This appears a very large percentage of loss, but when we take into consideration the enormous loss in the ordinary furnace this almost seems trifling by compari on. Of course this estimate takes the total or theoretical heat as contained in the coal. The Siemens furnace requires great care in its management, and is said to be more useful for heating large masses of iron for forgings or long bars than for puddling or the intricate processes of iron manufacture.

If I have been so fortunate as to make my description intelligible, it is clearly evident that this must be, and really is, a very economical furnace. None of the combustible gases can escape, and what is of very great importance is the exactness with which the air can be supplied. I have purposely omitted a great many details which those among you acquainted with the furnace will perceive, but I only wished to convey a general idea of its construction, and have introduced it here on account of its novelty and ingenuity. At the same time I by no means accept it as, in all respects, a model on which to construct furnaces, but it is celebrated as the best at the present time for some purposes.

Siemen's furnace, however suitable for large establishments where a great number of furnaces have to be supplied with gas, is clearly too cumbrous and costly for smaller places, and the question arises—can we not effect, approximately at least, a similar result in single furnaces to what is done by the Siemens furnaces? I think so.

We will now consider our furnaces as at present constructed, and why they are so wasteful. We hear a great deal about thin fires and regular charges in the ordinary furnace; and this is quite correct, inasmuch as it is the only way by which a right supply of air can be introduced to mix with and consume the gases. There are always two dangers we have to avoid. One is too much air, which is the least of the evils, and in which case a very large body of air passes away unconsumed, but it also carries away with it a certain amount of heat which cools the furnace and impedes the draught. The other evil of too little air is still more injurious, for the gases having only a small share of the oxygen required are burned into carbonic oxide, and this very often accounts for the deficient supply of steam from a boiler in consideration of the coal burned. But these fires are liable to burn into holes and admit streams of cold air; nor is this the only objection, for when the fire is fed with fresh coal, which must of necessity be very often, the new coal absorbs a large proportion of the heat of a thin fire, and immediately lowers the temperature. The fire contains a certain number of units of heat. If twice the quantity of coal was in active combustion there would be double the number of units of heat, and it could therefore more easily sustain the reduction of temperature following a fresh charge of coal. I imagine the distillation of gas from coal or volatilization is a process similar to steam carrying off the heat from boiling water. The coal at first becomes an absorbent of the heat and then liberates the gases, and the volatilization of the bituminous portion of the coal acts in a similar manner to the production of steam, as I have said. The process is one of the most energetic known in cooling, because there is so large a portion of the heat converted from the sensible to the latent state. Regarding the quantity of air required in the ordinary furnace for the combustion of coal, I suppose very few people have any idea of the magnitude of the demand. It is generally given as 300 cubic feet, or 24 lb. of air to 1lb. of coal. Let us place this in another light. In my own establishment in Gateshead I have seven furnaces, each of which uses about one ton of fuel per day, in all about seven tons; therefore $7 \times 24 = 168$ tons of air required. Again, a pound of coal requires about 300 cubic feet of air. If we imagine the 168 tons of air made into a long stream of one square foot in area, the total length will be 21,381 miles in length. Another great cause of the loss of heat, as before stated, is the quantity of heat continually passing away to the chimney. I have said that a furnace may be more efficient for one kind of fuel than another; but the principal causes of loss in the ordinary furnace I have stated

above, and which I will again enumerate here:—(1) Loss of coals in firing. The best coal is often small and very brittle, and in stirring the fire a large quantity falls through the spaces between the bars, more especially when there is a necessity for hard firing to promote combustion; (2) the loss from unconsumed gases passing away, being burned into carbonic oxide from want of the requisite quantity of air; (3) loss from too much air, either from the fire burning into holes and allowing the air to pass through, or absence of means for regulating its admission; (4) loss of heat by radiation through the walls of the furnace; (5) loss from the quantity of heat passing to the chimney. One difficulty—that is, regulating the supply of air to the furnace—can only be overcome by artificial means, either by a fan-blast or steam-jet. I believe the time is fast approaching when the supply of air to furnaces will be regulated in this way as the most efficient and economical, and as obviating a great many of the faults of our present furnace. The idea is old enough. However, the arrangement of furnace I will describe presently may or may not be new. I never saw it before, nor am I aware that anything of the same kind has been tried, and to it I have added a supply of air by means of a blower. In this furnace, of which the drawing is a longitudinal section, the coal is introduced from the top, and is always on the top of the incandescent fuel, at the side of the furnace furthest from the place where the flame makes its escape. The hearth is of fire-brick, and during the meal hours all the ashes and clinkers are removed by the hole in the side of the furnace. The area of the hearth is about two-thirds of the area that it was previously; the blast is introduced above the new coals, and passes through them. As the coals begin to ignite, all the inflammable gases are forced through the fire, and at the same time mixed with air. The advantages with this kind of furnace seem to be the following:—(1) The whole of the gaseous products are made available; (2) there is entire absence of smoke, in consequence of perfect combustion; (3) there is a smaller quantity of air required, probably about one-fourth less, that is, about 18 lb. to 1 lb. of coal; (4) no increase of temperature above the external air is required in the chimney, and the escaping heat from the furnace can be used for other purposes; (5) a higher temperature in the furnace, and more rapid circulation of heat; (6) the perfect control which the attendant has over the furnace as regards temperature, getting the fire lighted and into operation in less time, when they have not been in use. There is also another very important point in connection with this method of making reheating furnaces—that the air can be so nicely adjusted by means of the blast and damper as to insure that nearly all the oxygen will be taken up by the carbon and gases, in consequence of which the iron is heated with scarcely any loss from oxide or scale. The balance of pressure can be made so that even when there are unprotected inlets to the interior of the furnace, the flame can be made to come to the edge of the open space. I believe the efficiency of the furnace might be largely increased by using hot air, which might be done by passing it through pipes or brickwork placed in the flues; for if we have the heat of the furnace 2500 deg., and the entering air heated to 500 deg., the result would necessarily be a great saving. On this point we have the experience of blast furnaces as an indication of what might be saved by this means alone.

The application of this method of constructing furnaces is more difficult to existing steam boilers, and this we can only accomplish by constructing a separate combustion chamber, in which the gases could be properly ignited before passing below the boiler. There is no doubt that the furnaces of ordinary steam boilers are extremely faulty. A long tube of small diameter, in which the complicated processes of mixing the air with the combustible gases, of distilling these gases, and igniting them while they are hurried away over the surface of the plates of the boiler at high speed, cannot in any sense be made economical. In this case these fires are really indispensable, and while we have the cooling effect inseparable from the distillation of gas from coal, and then the cooling effect added of the flame coming in contact with the boiler which has to be heated. Dr. Ure says on this point, "When a boiler is set over a fire it should not be too near the grate, lest it refrigerate the flame and prevent that vivid combustion of the fuel so essential to the maximum production of heat by its means; and this is simply what we do. Marine boilers have all the faults enumerated above. There is,

however, more reason for their use in this manner, from the small space they are allowed to occupy for the work they have to do; but even in this class of boilers the principle of the blast might be introduced with advantage, if the furnaces were made a little larger in order to allow a thick layer of coal on the bars. There would be, of course, danger to the boiler either from a stream of flame or cold air being projected against the plates. Another cause of waste in marine boilers arises from the furnaces and tubes having to work a long time without being properly cleaned. My own experience in more than one of the large Atlantic steamers showed that on beginning a voyage with clean boilers the consumption of coal per indicated horse-power was about 5 lb. of coal; after ten days it had increased to 10½ lb. of coal per horse-power. I have mentioned a stream of cold air as being sometimes dangerous to a boiler. I will here give an example from my own experience. One of the forward furnaces about nine days after starting our voyage began leaking badly and put out the fire; we got it repaired in port, and some time after it gave way again at the same place, for some reason. We had shortened the lower bars in that furnace, and this brought the bridge forward nearer the mouth of the furnace; in the course of time the portion of the bridge above the bars got worn and sloping backwards. There was a windsail or ventilator in front of this furnace, which brought cold air down from above to the boiler-room; it struck me this was the cause of the mischief. When the men were cleaning the fire out—this is done every eight hours—the cold air rushing down the windsail entered the furnace with great velocity, having the impetus of its own force and the draught in the furnace, and striking against the bridge was deflected by the angular point against the plate in the furnace, or rather at the bend upwards from the furnace towards the tube plate, which by the violent contraction gave way."

I have again to mention that a furnace which will suit admirably for one kind of coal will not answer for another. Thus, the conditions under which coke and anthracite coal enter into combination with oxygen are much less complex than in burning bituminous coal, and the great point to be observed is that a large quantity be kept on the bars; there is not so much danger of the carbon passing away without its supply of oxygen—in fact it cannot do so, as it cannot rise until it has its quantity of oxygen to liberate it. In bituminous coal the bituminous portion is only serviceable for heat when converted into gas, while the carbonaceous portions are consumed only in the solid state, and they must be separated, as explained, before they can be consumed. Thus, when coke or anthracite coal are burned, the products are carbonic acid gas and nitrogen; while with coal we have carburetted hydrogen, nitrogen, and carbonic acid gas or oxide.

Again, to enable us to compare the quantities of heat in different substances, we are compelled to use some standard by means of which any quantity of heat may be measured, and the standard generally used is the thermal unit, or quantity of heat required to raise 1 lb. of water 1 deg. Fah. In algebraical formulæ this quantity is usually shown by the letter J, in honor of Dr. Joule, who discovered this unit of heat. Dr. Joule found by careful experiments that the power developed by the fall of a pound weight through 772 ft. will raise the temperature of a pound of water 1 deg., and this is called the mechanical equivalent of heat. The investigations of Messrs. Faber and Silberman regarding the total heat of combustion in thermal units are generally recognized as the standard now, and they have been condensed by the late Professor Rankine, of Glasgow, as follows: "The burning of carbon is always complete at first, that is to say, 1 lb. of carbon combines with 2⅔ lbs. of oxygen and makes 3⅔ lbs. of carbonic acid; and although the carbon is solid immediately before the combustion, it passes during the combustion into the gaseous state, and the carbonic acid is gaseous; this terminates the process. When the layer of carbon is not so thick, and the supply of oxygen is not so small but that oxygen in sufficient quantity can get access to all the solid carbon, the quantity of heat in thermal units is 14,500 to each pound of carbon. But in other cases, part of the solid carbon is not supplied directly with oxygen, but is first heated and then dissolved into the gaseous state by the hot carbonic acid gas from the other parts of the furnace. The 3⅔ lbs. of carbonic acid gas from 1 lb. of carbon are capable of dissolving an additional pound of carbon, making 4⅔ lbs. of carbonic oxide gas, and the volume of this gas is double of that of the carbonic acid gas which produces it.

In this case the heat produced, instead of being that due to the complete combustion of 1 lb. of carbon, which is as we have said = 14,500 units, falls to the amount due to the imperfect combustion of 2 lbs. of carbon burned to carbonic oxide; thus = 2. × 4.400, being the number of units of heat in carbonic oxide = 8,800 units, showing a loss of heat = 5,700 units, which disappears in volatilizing the second pound of carbon. Should the process stop here, as it does in furnaces badly supplied with air, the waste of fuel is very great, as the carbonic oxide has a large quantity of carbon in it which is dissipated in the air without any useful effect. But when the $4\frac{2}{3}$ lbs. of carbonic oxide gas, containing 2 lbs. of carbon, is mixed with a sufficient supply of fresh air, it burns with a blue flame, combining with an additional $2\frac{2}{3}$ lbs. of oxygen, making $7\frac{1}{3}$ lbs. of carbonic acid gas, and giving additional heat of double the amount due to the combustion of $1\frac{1}{3}$ lb. of carbonic oxide; that is to say, 2 lbs. of carbonic oxide 10.100 × 2 = 20.200 units, to which being added the heat produced by the imperfect combustion of 2 lbs. of carbon, or 4.400 × 2 = 8,800, there is obtained the heat due to the complete combustion of 2 lbs. of carbon, or 14.500 × 2 = 29,000 units. Knowing the total number of thermal units in any combustible, we can soon ascertain the highest temperature that can be produced in the furnace with any kind of fuel; the products of combustion of coal being carbonic acid, nitrogen, steam and ashes. And if we take the means of the specific heat of these products, we find that they come very near the specific heat of the air. Again, as 12 lbs. of air will supply as much oxygen (supposing the whole of the oxygen to be taken up) as will be sufficient for the combustion of 1 lb. of carbon, the total weight will be 12 lbs. of air + 1 lb. of carbon = 13 lbs. Now the total heat of carbon we have seen is 14.500 units of heat, and the mean specific heat of the products of combustion is 0.238; thus this mean specific heat × 13 lb. of air = 3.094 and $\frac{14500}{3.094}$ gives 4691 deg.; this, however, is on the supposition that every atom of oxygen is used. If twice that quantity is used, as is usually the case, then the temperature will be 2437 deg. If we take a forced draught by fan or otherwise, by the same calculation we arrive at a temperature 3137 deg. —the supply of air being 18 lb. to one pound of carbon. These figures are rather complicated to carry in the mind, and perhaps might have been dispensed with here. But there is one result we arrived at in their use we may follow a little further—we find that there are 14,500 units of heat in a pound of carbon, which if it could be all used in a steam engine would give stupendous power; we found that the unit of heat = 772 foot-pounds and 14,500 × 772 = 1,119,400 = or 339-horse power; and therefore, when we speak of a loss of about 60 per cent., we are left with 136-horse power; and as in the Seimens furnace he claims to save 40 per cent. on the latter, we arrive at 190-horse power from one pound of carbon. It is supposed that in some instances we have realized about 70 per cent. of the theoretical heat in fuel. This I would be inclined to doubt. We have seen that with the ordinary furnace we lose about 25 per cent. in getting a draught; we have to add to this loss from small coal, too much or too little air; the products of combustion flying off to the chimney at a speed of 30 ft. in a second in some instances, it must be abundantly clear that 50 per cent. of the heat of fuel we use is lost. It was stated not many weeks ago that, in some processes in connection with the manufacture of iron, the quantity of fuel used was sufficient to produce the desired result fourteen times if properly applied. I think it is clear we begin by placing the chimney at the wrong end of the furnace, and the air ought to be driven in, not drawn though. We have seen that when a blast is used we can have a pressure in the furnace sufficient to balance the pressure of the atmosphere. The waste heat could also be made to do work in passing away. I dare say most of us now present can recall instances to our mind where a number of furnaces are used, and where the heat of one, if it could be retained and applied, would be amply sufficient. The blast, then, is the only means of doing it, and I do not think the time is far distant when the hideous pillars we seem so fond of now will be no longer seen.

I have implied that the position in which we find ourselves with regard to the cost of the materials and labor will probably accomplish more in this direction than the mere intellectual activity of a few eminent men striving after greater perfection, because they will not be listened to until

penuriousness compels attention. Thomas Carlyle says very finely, "Alas! there is no possibility for poor Columbus now at any of the public offices, till once he becomes an actuality, and says, 'Here is the America I was telling you of.'" A hopeful sign, however, and one sure to have beneficent results, is the exhibition to be held in Manchester in a short time on this subject. There is indeed plenty of room for improvement; there is an abundance of facts on which to exert our reasoning powers, and ample space for experimental research. We want new ideas or thoughts, which, after all, govern the world. This is at least the lesson which our experience teaches as we grow older; and if with our progress we learn a wise humility, we will also learn that the more we know and acquire, the more our ignorance and dependence become apparent to ourselves. We learn also that, strive as we may, we never get beyond the border-land of knowledge, and that there are secrets beyond that boundary which will never be revealed on this side of the great change which awaits us all.

BLOWPIPE ANALYSIS.*

From "Iron."

Probably no one instrument is of more use to the thoroughly practical chemist and assayer than the blowpipe, and yet none is more unjustly neglected. It is a matter of common observation among those who watch students that they rush over the "preliminary examination" of the unkown substances given to them as exercises, with an unwise haste, anxious to reach what appears to them the real business of analysis. Many a time have we seen a judicious teacher check his careless pupils, and show them, with blowpipe, tube and charcoal, how they can ascertain not merely the road which they ought to follow in making a full analysis, but how, with these simple implements, they may learn in a few minutes almost as much as they need, in the majority of practical cases, about an unknown or commercial product. We by no means think that blowpipe analysis should be practised to the exclusion of the wet method; but we are strongly of opinion that it deserves a great deal more attention than it usually receives. A brief consideration of the development and present condition of this branch of chemistry will justify this opinion.

The blowpipe, in the common form still in use by braziers and other workers in metal, has been used in the arts for ages—possibly even by the ancient Egyptians. In the early part of the eighteenth century it appears first to have been employed for scientific purposes, by Anton von Swab, a Swedish mining director. He seems to have used the blowpipe for the discrimination of ores and minerals. His countryman Cronstedt, the mineralogist, was largely indebted to the blowpipe in erecting his chemical system of mineralogy, an account of which he published in 1758, and in von Engeström's English translation of this work appears a full account of Cronstedt's method of using the blowpipe, and of the behavior of minerals before the blowpipe flame, alone and with fluxes. Bergmann greatly extended the usefulness of the blowpipe by employing it in qualitative examinations of every kind. He proved that by the aid of this miniature furnace elements which had hitherto escaped detection by more formal methods could be easily discovered, and but for ill-health he might have done even more. His pupil Gahn carried on the work, and was so dexterous that by a simple examination of the newly-discovered mineral oxide of tantalum, he discovered that it contained less than 1 per cent. of tin. To Berzelius, however, we are indebted for the basis of the modern science of the blowpipe. Gahn did not record his experience, though he showed the greatest liberality in communicating his knowledge. He selected Berzelius as a favorite pupil, and to this eminent man we owe a work which was long the standard one upon the whole subject, and which may still be consulted with profit.

After Berzelius came Harkort, who established the practicability of employing the blowpipe in far more delicate work than had previously been attempted, or even

*"Plattner's Manual of Qualitative and Quantitative Analysis with the Blowpipe." From the last German edition, Revised and Enlarged. By Professor Th. Richter. Translated by Henry C. Cornwall, assisted by John H Caswell Second Edition, revised. (New York: D Van Nostrand: London: Sampson Low.) 1873.

conceived possible. Hitherto only qualitative determinations had been aimed at with the blowpipe. Harkort, in 1827, perfected a quantitative blowpipe assay of silver. His early death stopped his prosecution of this line of research ; but Plattner proved himself a worthy successor, and we have in the work before us a compendium of almost all that is known of this important branch of practical chemistry. The book is truly Teutonic in its ponderousness, its minuteness of detail, and its comprehensiveness; but it is a worthy neighbor of Fresenius on our shelves, and calculated to be quite as useful. Possibly it may be somewhat too full—there is some evidence of this in a few places where the translators confess that they have not wholly followed the minute details of the original—but in a book of reference this is more pardonable than deficiency.

Perhaps our readers will obtain a better idea of the nature of this book if we refer in some detail to two or three selected sections. We must premise that the first 120 pages comprise a description of apparatus, manipulation, etc., and tables of reactions, in which we should like to have seen included, as closely related to the subject, the reactions with the Bunsen burner, recently described by Bunsen himself. Abstracts of these are, however, accessible in Mr. Vacher's last edition of Fresenius's "Qualitative Analysis," and in the "Owens College Junior Manual of Practical Chemistry." Two hundred and seventy pages are then occupied with an account of the behavior of minerals under the blowpipe, with instructions for not merely the detection of one or two components, but for their separation. This is useful information, though possibly none but a Plattner, Scheerer, or Richter would think of thus performing a detailed analysis. Upwards of a hundred pages are devoted to the description of quantitative blowpipe analysis, an appendix and two indexes completing the work. The fact that the index of minerals and metallurgical products described occupies twelve pages of small type, is proof enough of the comprehensive manner in which the subject is treated. An abstract of the sections relating to iron will confirm this, if confirmation is wanted. First is given a list of 120 minerals and metallurgical products in which iron occurs, described in brief detail, as for example:—"Chromite (chromic iron), (FeO,CrO,MgO)(Cr_2O_3,Fe_2O_3,Al_2O_3), occasionally also containing a little MnO and SiO_2; the amount of FeO varies from 20 to 36 per cent." Then we have instructions for the examination for iron, which include the blowpipe characteristics of the minerals and metallurgical products before mentioned, and are divided under various headings. The mere detection of iron in any of its common salts is, of course, perfectly simple, the borax bead or the magnetic residue—each of which tells its story plainly—being easy to obtain. The difficulty is when some other element is present to mask the reactions. Cobalt may be taken in illustration, as the magnificent blue produced by its protoxide with borax completely overpowers the pale iron color. In this case we are recommended to soften the bead upon charcoal in the reducing flame, and then fuse it upon platinum wire in a pure oxidizing flame. If this makes it so dark as to be nearly opaque, the soft glass is pinched out, some of it broken off, and the remainder diluted with more borax. The cobalt is thus, as it were, washed out, while the oxidizing flame is employed to convert all the iron into the sesquioxide, which, of course, gives its characteristic yellow or brownish red color, according to the amount present. The volatile metals, as well as sulphur and arsenic, may be driven off by continued heating on charcoal in the reducing flame. Those not thus volatilized, such as copper, may be separated partly by reduction on charcoal and partly by the solvent action of borax or by lead. Various ingenious devices for these purposes are described. A few points worth recollecting by the student—and just those he is least likely to discover for himself—are those relating to the colors of borax or phosphorus-salt beads when containing a mixture of oxides. Iron peroxide, of course, gives a yellow or brownish bead, which may be overpowered or changed to green by cobalt; the blue of copper also makes it green while hot, and a little lighter green on cooling. This fact is utilized to determine whether iron is present as per- or protoxide, the assay being added to a borax bead containing oxide of copper. With sesquioxide of iron the bead becomes bluish green, with protoxide red spots of cuprous oxide become distinctly visible in it. Manganese in quantity completely obscures iron, producing in the outer flame a bead dark-red

while hot, and red, inclining to violet, on cooling. Reduction of the manganese to protoxide leaves the iron coloration alone; this in case of a small quantity of manganese can be effected on platinum wire, otherwise it is well to shake off the hot bead and heat it on charcoal in the reducing flame with tin.

Some of these separations, however, especially the quantitative ones, cannot wholly be effected in the dry way. An illustration of this is found in the treatment of a mixture of oxides of iron and chromium. In this case the color of the hot bead shows iron, but when cool only chromium. Though this gives the means of making a very good guess at these oxides, it is hardly sufficient to indicate the existence of iron with certainty. Hence, nitre and carbonate of soda must be used to convert chromium into alkaline chromate, which is dissolved out, the residue being fused up with borax again, when, if other coloring oxides are absent, the coloration of iron is obtained.

The quantitative assay of iron next described is really a combination of the blowpipe and the wet methods, intended for use only when the appliances for more accurate methods are not at hand. Very small quantities are employed, an assay centner—the weight usually taken—being equal to a hundred milligrammes. The method—which we need not describe in detail, referring our readers to the book itself—is essentially that of precipitating ferric oxide by ammonia, fusion with carbonate of soda being employed when necessary, and alumina being dissolved out by caustic potash. The constituents of an ore which occur in any quantity, such as silica, alumina, and lime, can also be determined by the simple methods described, while others, as manganese, baryta, sulphur, phosphorus and arsenic, may be detected, though their estimation can only be effected by regular analysis.

It is not to be expected that more than a small minority of assayers will ever be able to practise these methods with dexterity. But the mere attempts of a student to carry out these instructions of Plattner cannot fail to benefit him beyond a little. The best workmen frequently work with simple tools—witness Davy with his teacups—and very often even ordinary workmen are placed where only simple tools are available. So much can be done with the blow-pipe and its auxiliaries, which may all be carried in the coat pocket, that mineral explorers ought to make it a matter of duty to know how to use it, and we know of no book—after the A B C of blowpipe-work has been mastered—in which author, translators, and editor have done more to aid such students than the one before us.

ON THE ELECTRO-MOTIVE FORCE OF FLUID BATTERIES.

From "The Telegraphic Journal."

This subject is studied by M. Paalzow in a recent number of "Poggendorf's Annalen." Kohlrausch alone appears to have previously endeavored to determine the electro-motive forces of liquids by the electrometric method ("Pog. Ann.," Bd. 79, p. 200). M. Paalzow repeated his experiments, but without success. The quantity sought is not only masked, but often exceeded by electricities, which the insulators of the measuring apparatus accumulate, and which, in the manipulations that are necessary, always recur.

With aid of the galvanometer, on the other hand, some good results have been obtained. Wild has shown that there are liquids which follow Volta's law of tension; Du Bois Reymond, that by insertion of distilled water into the series of members of liquid batteries, the highest value of electromotive force of liquids is attained. Worm-Muller considers that water is electromotively indifferent towards all liquids, from the fact that Kohlrausch has found no difference of tension between water and nitric acid, and that the thermal currents between water and other liquids are extremely weak. Two other facts appear to contradict this hypothesis: Faraday found that distilled water, in friction with other substances, gave the highest tension; and Quincke, that diaphragm-currents are considerable only with distilled water.

M. Paalzow's observations refer chiefly to the influence of the nature of the separating surface on electro-motive force, the constancy of this force, and the compensation for current work.

Previous experimenters have thought it indispensable to have a sharp surface of separation between the liquids. M. Paalzow at first fulfilled this condition. He specially studied a liquid battery consisting of amalgamated zinc in sulphate of zinc, hydrated sulphuric acid, distilled water, sulphate of zinc with amalgamated zinc. The liquids were in a series of large U-tubes, the first containing sulphate of zinc, the second sulphate of zinc and sulphuric acid, the third sulphuric acid and distilled water, the fourth water and sulphate of zinc, the fifth sulphate of zinc and the electrode of amalgamated zinc. The zinc electrodes were connected with a Wiedemann mirror-compass and the electro-motive force was measured by the method of compensation.

The sharp separating surface was obtained (between sulphate of zinc and sulphuric acid, *e. g.*) thus:—The sulphate was first poured into the U-tube, then the other liquid poured through a funnel with its very fine orifice at the surface of the sulphate of zinc, and a good deal of blotting-paper in the wider part. Adjoining tubes were bridged over by a syphon tube, the ends of which were bent upwards in the liquid.

Having compensated such a battery, M. Paalzow disturbed the several separating surfaces with a glass rod, and he found that the electro-motive force continued the same, the needle of the compass remaining at zero. Thus, in liquid batteries, a sharp surface of separation is not of consequence, if care be taken that one liquid do not penetrate through the second to the third. This was prevented in the present case, the liquids in the syphon tubes remaining unaltered.

While the result was surprising, it might as the author remarks, have been expected; for only in solids is a sharp surface of separation possible.

The battery described continues a pretty long time constant, owing to the great resistance and the consequently small current-work. After some time the electro-motive force decreases, owing to chemical processes. The positive current has, in the battery, the direction from sulphate of zinc to acid, to water, and to sulphate of zinc. Thus, through electro-chemical processes, there is at the zinc pole of vessel I a dissolving of the zinc; at the surface of separation between sulphate of zinc and sulphuric acid, formation of sulphuric acid; at that between sulphuric acid and water, formation of water, at that between water and sulphate of zinc, formation of sulphuric acid; and at the last zinc pole separation of zinc. Thus, after some time, sulphuric acid is inserted between the water and the sulphate of zinc, and owing to the symmetrical arrangement now approaching in the liquids constituting the battery, the electro-motive force must gradually be reduced to zero. Considering, in the case of liquid batteries, the chemical process in the battery itself, it readily appears that only those batteries can furnish a constant electro-motive force, in which all the constituent liquids contain either the same acid or the same radical.

According to the principle of conservation of force, we expect a compensation in the battery itself for the current afforded. In the battery under consideration, sulphate of zinc, hydrated sulphuric acid, water, sulphate of zinc, one would seek this compensation in the caloric processes between the constituent liquids. From these the chemical processes, in reference to their calorific values, are, as previously shown, eliminated; there remain for compensation, only the processes of diffusion. To ascribe it to these. M. Paalzow thinks impossible, for he has found a battery in which, through processes of diffusion, only cold is produced, and which yet furnishes a strong current. This is the combination: Sulphate of zinc, muriatic acid, acetate of protoxide of zinc, sulphate of zinc, between zinc electrodes. Of the diffusion process here, muriatic acid mixed with sulphate of zinc gives a lowering of temperature; also muriatic acid with acetate of protoxide of zinc; acetate and sulphate of protoxide of zinc mixed, give no change of temperature.

"I distinguish, however, in the hydro-batteries generally, those chemical and diffusion processes, which also occur with the open circuit, from those which are called into play through closure of the circuit. It is only to the calorific values of the latter that the compensation for current work can be attributed. This may be explained with a Daniell element. If in constructing such we use amalgamated zinc, which, before closing of the circuit is hardly attacked at all, then, after closing, the entire calorific value of the chemical process in the battery is equivalent to the current-work.

If, however, unamalgamated zinc be taken, there are two chemical phenomena to be distinguished—the dissolving of the zinc which would occur even in the open circuit, and that which is produced by the current. I have convinced myself by experiment that the purely chemical dissolving of the zinc in the closed circuit is equal to that which would occur in the open circuit, and that the current work corresponds only to the quantity of zinc which is dissolved by the current.

"A Daniell element was constructed, the zinc was not amalgamated, the circuit was open. The sulphuric acid had a sp. gr. 1.043. The zinc plate weighed before the experiment, 21.859 gr. After remaining twenty minutes in the open circuit, it weighed 21.114 gr., having lost 0.745 gr.

"A second Daniell element was made as like the first as possible. The circuit was closed, and the voltameter inserted (with copper electrodes in sulphate of copper). The unamalgamated zinc plate weighed, before the experiment, 21.893 gr.; and after the experiment, which lasted twenty minutes, 20.927 gr., having thus lost 0.966 gr. In the copper voltameter 0.244 gr. copper was separated out. The quantity of zinc equivalent to this, whose separation was attributable to the current, was 0.250 gr. In the closed circuit there was thus dissolved by the purely chemical process, which also occurred in the open circuit 0.966 gr.—0.250 gr.=0.716 gr. The quantity of zinc is almost the same as the first zinc plate lost in the open circuit.

"With the same kind of zinc and sulphuric acid of the same specific gravity, several experiments were made, the results fully agreeing with those described. This appears to me important in reference to the contest between the chemical and the contact theories (though I cannot here pursue the subject further).

"If, now, we were to ascribe the current-work of liquid batteries to the caloric values of the diffusion processes, it must only be those which appear in the closed circuit; and evidence must be furnished that the diffusion takes place differently in the closed circuit from that in the open. Hitherto, such proof is wanting. But according to the experiments with the battery, sulphate of zinc, muriatic acid, acetate of protoxide of zinc, sulphate of zinc, the current here can neither be attributed to the one nor to the other, inasmuch as cold is produced by the diffusion.

"I incline, therefore, at least in the case of liquid batteries, to Nobili's opinion, that the currents produced by them have similar origin to that of thermal currents, and that the compensation for the current-work is to be sought in the heat absorbed from without. I am at present occupied in experimentally testing this view."

ON RECENT DISCOVERIES IN MECHANICAL CONVERSION OF MOTION.

From "The English Mechanic."

The following is an abstract of the official report of the lecture delivered by Prof. Sylvester, F.R.S., at the Royal Institution, the chief discovery of which it treats being that known as Peaucellier's parallel motion. The report is accompanied by voluminous and instructive notes, for which however we have not space. The speaker stated that the subject he proposed to bring under the notice of the meeting related mainly to the discovery of a perfect parallel motion, that is to say, of a mode of producing motion in a straight line by a system of pure link-work without the aid of grooves or wheel-work, or any other means of constraint than that due to fixed centres, and joints for attaching or connecting rigid bars. This important discovery was made by M. (now Colonel) Peaucellier, an officer of Engineers in the French Army, and first published by him, in the form of a question in the "Anneles de Mathamatique" in the year 1864. Before Peaucellier's time all so-called parallel motions were imperfect, and gave merely approximate rectilinear motion; in substance they will be without exception found to be merely modifications of Watt's original construction, and to depend on the motion of a point in, or rigidly connected with a bar joining the extremities of two other bars rotating round fixed centres, which may be described briefly as three-bar motion. Peaucellier's exact parallel motion depends on a link-work of

seven bars moving like Watt's, and the other imperfect parallel motions of the same class round two fixed centres.

To understand the principle of Peaucellier's link-work, it is convenient to consider previously certain properties of a linkage, (to coin a new and useful word of general application), consisting of an arrangement of six links, obtained in the following manner:—first conceive a rhomb or diamond formed by four equal links joined to one another; and now suppose a pair of equal links to be joined on to two opposite angles of such figure and to each other. All six links are supposed to lie (and to be constrained by the nature of their attachments to remain) in the same plane. The point of junction of the last-named pair of links (which it will be found convenient to call the fulcrum) according as they are greater or smaller than the sides of the diamond, will lie outside or inside the diamond. The linkage consisting of the six links may be termed a positive *cell* in the one case and a negative *cell* in the other.* It is easily seen, as a geometrical necessity, that the fulcrum, in whatever way the linkage is moved about, will always lie in a straight line with the two free angles of the diamond, which may be called its poles, and the distances of these poles from the fulcrum, or the ideal lines which represent those distances, may be called the arms of the cell. It is upon the geometrical relation between these arms that the remarkable mechanical properties of Peaucellier's cell depend. The cell may be made to change its form like a set of lazy-tongs or any other kind of linkage, by closing or opening the diamond; as this is done evidently the lengths of the arms alter; but it will be found, and is capable of easy geometrical proof, that they remain subject to a very simple condition, viz., one increases just as much as the other decreases, so that their product remains invariable; this product is equal to the difference between the square of either of the links (called the connectors) proceeding to the fulcrum and the square of any side of the diamond, to which we may give the name of the modulus of the cell. The speaker illustrated this property experimentally, using a negative cell for the purpose. When the fulcrum was midway between the two poles each arm was 12in. in length. When one arm was made 18in. the other was found to be 8; when again it was stretched to the length of 24in. the other was 6, and so on, the product of the two remaining always 144; or, reckoning in feet, to the lengths 1, 3-2nd 2, 3 of one arm corresponded the lengths 1, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$ of the other; showing that the length of one arm was so governed by the length of the other as that the numbers denoting the two were always inverse or reciprocal to each other when the modulus is taken as unity. Hence a Peaucellier's cell may be conveniently termed a Reciprocator or Inverter. If we were to suppose the connectors at their free ends, instead of being attached to the side angles of the diamond, to be joined on to two adjoining sides in such a manner as to become parallel to the other pair of sides, this parallelism would continue to subsist for all positions of the linkage, and the arms or distances of the fulcrum from the opposite angles or poles of the diamond would still remain in the same right line, but the relation between them would now be one of direct instead of inverse proportion. Conceive the fulcrum in such an arrangement to become fixed. Since we cannot only alter the angles of the diamond, but make the whole arrangement turn round the fixed point, we can make either pole describe any plane curve whatever; the other pole will then describe a curve precisely similar in shape, but drawn on a different scale, as in any ordinary pantigraph.

But if we revert to the Peaucellier cell or Reciprocator, whether of the positive or negative form, and treat it in the same manner as the supposed pantigraphic arrangement, fixing the fulcrum, and making one of the poles—*i. e.* an extremity of one of the arms—describe any plane curve, the other pole will no longer describe a similar curve, but what in the language of geometry is termed an inverse of the curve in question, the fulcrum being the origin of the inversion.

* Mr. Penrose, the architect, and surveyor to St. Paul's Cathedral, has put up a house-pump worked by a negative Peaucellier cell, to the wonderment of the plumber employed, who could hardly believe his senses when he saw the sling attached to the piston-rod moving in a true vertical line, instead of wobbling as usual from side to side. There seems to be no reason why the perfect parallel motion should not be employed with equal advantage in the construction of ordinary water-closets. The author has been admitted to see the geometrical pump at work in Mr. Penrose's kitchen at Wimbledon. A sister pump of the ordinary construction stands beside it. The former, although quite as compact as its neighbor, throws up a considerably larger head of water with the same sweep of the handle. Its elegance, and the frictionless ease with which it can be worked (beauty as usual the stamp and seal of perfection) have made it the pet of the household.

Suppose now one of the poles is made to describe a circle, the other will describe the inverse of a circle, which geometricians are well aware will in general be another circle, subject to the exception that if the arc described by one pole is part of a circle passing through the fulcrum which is here the origin of the inversion, the path of the second pole will be no longer a circle, but a perfect straight line, which, under a mathematical point of view, may be regarded as a circle with an infinite radius. If, then, in addition to fixing the fulcrum, we still further constrain the motion of the Peaucellier cell by attaching one of the poles to a centre (which for the sake of distinction from the other fixed point above defined we may term the *pivot*) round which it can revolve, situated at an equal distance from that pole and the fulcrum, the other pole will describe a perfect straight line perpendicular to the line joining the fulcrum and the pivot. We have thus a combination of seven radiating bars attached to two fixed centres, one point of which describes a true rectilinear path, and thus the long-sought-for problem of a perfect parallel motion meets for the first time its complete solution.

The speaker illustrated these results by various models constructed in wood. By changing the length of the radial bar connecting one pole of the cell with a fixed point, the free pole was shown to describe arcs of circles convex or concave to the fulcrum, according as the ideal circle, in an arc of which the first-named pole moved, fell short of the fulcrum or contained that point within it; in the limiting case, when it passed through the fulcrum, the path was shown to be neither convex nor concave, but a straight line free from all curvature in either direction. This was further verified mechanically by connecting together at their free poles two perfectly equal and similar mounted cells. If the tendency of either of these was to deviate from the straight path, the tendency of the other would be to deviate in the contrary direction; so that either the pair of mounted cells would become an absolute fixture, or the two would crush or tear each other to pieces; but in the experiment exhibited, the pair of mounted cells were seen to move together (as if in happy wedlock), without let or hindrance to each other's motion. The circular motion of the free pole of a single mounted cell in the general case was also verified experimentally, and even more simply than in the rectilinear case, by the addition of a second radial bar, taken of a suitable length, determined by previous mathematical calculation. As a general rule, the total number of bars in a link-work machine must be odd, but here there were eight bars, and yet the combination admitted of being set in free motion—any one of the eight being, in fact, what may be termed a lazy-bar, and capable of being removed without disturbing the motion, very much in the same way as any one of the four legs of a table may be removed without disturbing the equilibrium.

The speaker pointed out the important applications of the two kinds of motion above referred to (which he proposed to call the circulo-linear and the circulo-circular respectively) to various constructions in machinery, such as the steam-engine, planing and grinding machines, the construction of maps on the stereographic projection, millwright's work, laying out of railway curves, dioptric apparatus for light-houses, ornamental tracery, pendulum suspension to effect motion in a practically exact cycloidal arc, &c., &c., and referred to the use which, as he was informed by the authorities at Woolwich, might have been made of the circulo-circular adjustment in saving several week's work, inconvenience, and expense in cutting out the fish-bellied torpedo casings recently constructed in the laboratory department at the Royal Arsenal there, and the use contemplated to be made of the circulo-linear, or perfect parallel motion, for guiding a piston-rod in certain machinery connected with some new apparatus for the ventilation and filtration of the air of the Houses of Parliament, now under course of construction.

He next referred to the unlimited command over the motion of a point furnished by a combination of cells. Returning to the simple Peaucellier cell, its use may be modified in a very remarkable manner by setting free the point of junction of the two connectors (termed, in what precedes, the fulcrum), and fixing one of the poles as a centre of rotation in its place. If now the liberated fulcrum be made to describe any curve, the free pole will describe a curve corresponding to it, according to a certain easily-statable mathematical law. Imagine the first-named curve to be part of a circle passing through the fixed point—it may be shown that in that case the free pole will describe the inverse of a conic section in re-

spect to a vortex of the conic as the origin of the inversion; consequently, by combining with this cell a second, used as a Reciprocator, we may, mounting with a suitable radius a pair of Peaucellier cells duly adjusted, cause a point to move in a parabola, ellipse, or hyperbola.

The speaker exhibited a combination of this kind, and caused a point to describe portions of an ellipse, a parabola, and of the two branches of a hyperbola in succession; the traversing pole of the first cell, which might be termed the first follower, being seen to describe beautiful nodal cubics (or the inverses of the conics), while the free pole of the second cell or second follower described the conics themselves.

He next went on to state that by a combination of cells properly proportioned and suitably attached to each other in succession in a manner similar or analogous to that in which simple machines, as for example, a number of levers, may be combined to produce a complex one, we are able to bring about any mathematical relation that may be desired between the distances of two of the poles of a linkage from a third, and are thus potentially in possession of a universal calculating machine. He exhibited and worked a cube-root extracting machine constructed on this principle, and claimed to have given the first really practical solution of the famous problem proposed by the ancients of the duplication or multiplication of the tube. This machine consisted of a combination of three cells; by changing the modulus of one of the three, he explained that it was also quite easy to solve the cubic equation involved in the analytical solution of the problem of the tri-section of the angle; and a working model of an instrument of this kind executed in zinc was exhibited by Professor Henrici after the lecture. He concluded by expressing his great obligations to this gentleman, without whose aid he would have been able to do little more than adumbrate in general terms the results which, thanks to his friend's practical knowledge and skill, he had had the pleasure of exhibiting in a tangible form, and submitting before his audience to the test of actual experiment.

BLAIR'S IRON SPONGE MANUFACTURE.

From "Engineering."

The manufacture of wrought iron and steel directly from the ore, has always presented great attractions to experts and ironmasters, because it dispenses with the roundabout method of the blast furnace; because it avoids the blast furnace combination of other metals and impurities with the iron, which metals and impurities, chiefly carbon, silicon, and in some cases phosphorus, have to be subsequently removed by additional and costly processes, in order to produce good wrought iron and steel; and because iron ore can be deprived of its oxygen, and thus made into sponge, without a melting temperature, and hence without rapid destruction of the furnace, and without blowing engines and other such costly machinery.

It is unnecessary to tell the student of iron metallurgy that the attractions of the direct process have won a host of admirers, whom it has led, like an *ignis fatuus*, through the quagmires of metallurgical chemistry and engineering, into the dismal swamp of bankruptcy. The crumbling remains of reducing furnaces in every country, are even stronger evidences of abortive effort in this direction, than are the historical literature of the iron manufacture and the assurances of certain distinguished experts that the thing cannot be done to commercial advantage.

But the failure of previous efforts does not disprove the correctness of the theory upon which these attempts have been founded, any more than the failures of Kelley and Shunk and Martien, and the oft and apparently hopeless early failures of Bessemer, disprove the correctness of Bessemer's theories, or limit the vast field of his operations.

It should appear from the history of iron metallurgy, and especially from the history of the Bessemer process, that every scheme that is well founded in chemistry, however refractory and hopeless may be its mechanical conditions, will ultimately be put upon a working basis; that ingenuity, coupled with persevering experimenting, will at last discover the missing link.

This appears to have been the case with the direct process. Mr. Thomas S. Blair,

of Pittsburg, U. S., an ironmaster of some 25 years' experience, a good chemist, and a gentleman of ample means and resources, having these advantages, and being perfectly familiar with the difficulties to be encountered, undertook this problem with the determination of solving it, however long it might require, and without the necessity or anxiety of ordinary inventors, to realize on an undeveloped idea. Some four years, not of random trials, but of consecutive steps, constantly guided by chemical determinations, and on a scale which made commercial probabilities constantly measurable, have brought the manufacture and utilization of sponge to the degree of chemical, mechanical, and commercial success to which it has now attained in America.

It is only necessary to mention here the grand difficulties which have heretofore rendered all efforts in this direction either abortive, or extremely limited in their application; the literature of the profession abounds with the details. The first difficulty was in securing the uniform reduction of a large amount of ore. A tube a few inches in diameter, filled with iron ore and the necessary carbon, averaging 30 per cent., and subjected to a red heat for a few hours, is a perfectly practical reducing furnace, chemically, but not a perfectly practicable one commercially. When furnaces were made large enough to fulfil the latter condition, it was found, even in the furnace of Chenot, the best before Blair's, that the central core of ore in the cylinder was not perfectly reduced. And it has further been ascertained that this want of uniformity in the product, especially the destructive action of the unreduced ore on the walls of the furnaces in which it was further manufactured, have rendered its use impracticable. The second grand difficulty has heretofore been the reoxidation of a part of the sponge, either while cooling, or while in or while being transferred in a hot state to the puddling or balling or melting furnace for further manufacture. As before stated, the professional literature on this subject will supply the details of previous failures from these causes.

It is not to be denied that Mr. Blair has had the advantage of the early experimenters in having the gas furnace and its high heats with comparatively neutral flames at his command for the purposes of further manufacture; but it is equally not to be denied that Mr. Blair has overcome previous difficulties inherent in the sponge itself; for the long continued sponge manufacture of Chenot (which was however at last abandoned for the reasons mentioned), and the best other sponge manufactures preceding Blair (all of which are now abandoned from the same causes), were known and practised long after the Siemens furnace was in use, and even after the Siemens-Martin process was in successful operation; but the previous sponges were never successfully used, even with the aid of the gas furnace.

The two grand features of Mr. Blair's system of reduction, which meets these two great defects of previous systems, will appear from an examination of the illustrations we publish on page 132, which show one of six nests of furnaces, now running at the Blair Iron and Steel Works, at Glenwood, near Pittsburg. The three firebrick reducing cylinders K are 4½ ft. in internal diameter, and stand 42 ft. high from the ground to the charging platform. They are surrounded (and supported as shown in Fig. 1) by a strong red brick stack R, lined with firebrick, and standing on the columns and establature M. Gas from ordinary producers is distributed by the pipes C D and the burners E to the annular spaces around the cylinders, where it meets jets of air and burns, encircling the cylinders with a uniform flame and keeping them at the necessary red heat. The products of this combustion pass off by the chimney Q. A cast-iron thimble J is placed as shown, in the top of the cylinder, a 5-inch annular space being left between the outside of the thimble and the inside of the cylinder. Into this annular space the ore, mixed with the necessary coal for its reduction, is charged. This thin annular charge is heated from without by the producer gases, as before mentioned. It is also heated from within by the combustion of producer gas admitted to H by the pipe F and air introduced by the pipe G. The carbonic oxide arising from the deoxidation of the ore below, also burns within the thimble. The heat thus communicated to the charge has only to penetrate it 2½ inches from either side, the result of which is, and obviously must be, the rapid and uniform heating of the ore and the carbon mixed with it. This having been done, the difficulties, as far as reduction is concerned, are over. Nothing more is neces-

sary but to keep the charge up to the temperature which it has acquired in the annulus, and to give it time for the chemical reaction to take place. It has been ascertained that with the proportions, shown in in the engraving, the charge acquires the necessary heat by the time it reaches the bottom of the thimble, and that it is perfectly reduced by the time it has descended to the bottom of the external heating chamber (L, Fig. 3), when it is passed through at the rate of 20 tons (of iron in the sponge) per week per cylinder, or 60 tons per week per three-cylinder furnace. Thus the first difficulty of previous reducing operations is overcome; the charge having been uniformly heated, and so surrounded by flame that it cannot get cool till reduction is completed, uniformity of reduction is absolutely secured.

Now, however, a new condition has arisen. The deoxidized sponge at a red heat is so sensitive to oxygen that it will take up air from the smallest exposure, and so be irregularly turned back into ore again. For this reason every attempt to remove the sponge in a red-hot state to a heating or melting furnace has been attended with great loss and irregularity of product. It is, of course, impracticable to seal the hot sponge perfectly against the entrance of air, either by air-tight discharge valves, or by a slight excess of pressure in the cylinder, for by the law of transfusion of gases, the heavy will rise into the light, and the light will descend into the heavy gases, unless there is a decided current to be overcome. Mr. Blair meets the difficulty by simply prolonging the cylinder below the zone of reduction, far enough to allow the charge itself to form a packing against the entrance of air. The lower part of this prolonged cylinder is cooled by the water jacket N N, and is made so long that the charge will in its regular descent from L to the floor, where it is removed, get cool enough to be held in the hand. At this temperature it will not oxidize for weeks. So that any air which may leak in from below comes in contact with cold sponge which it cannot hurt; and this column of sponge, compressed together by the superincumbent weight of all the charges above, prevents any air from penetrating where the sponge is hot enough to be injured by it. The sponge is withdrawn by lifting the sleeve P at the bottom of the cylinder. The cone O promotes the uniform discharge of the interior and exterior parts of the column of sponge. When the requisite quantity is drawn, the sleeve is driven tightly down to the floor, and luted with clay.

The working of the furnace is probably simpler and less likely to go wrong than any other metallurgical operation where heat is employed. It is only necessary to see that the charge, as it escapes from under the thimble into the body of the cylinder S, is sufficiently hot, and to draw the cold sponge a little more slowly if it is not; also to keep a uniform temperature in the external heating chamber by observing the flame through sight holes in the top of this chamber, and regulating the air and gas admission accordingly. It has been found much more convenient at Glenwood to use in this heating chamber gas which is originally free from tar, like that from coke or anthracite, or gas from which the tar has been removed by washing. By employing small coke—the *débris* of coke yards—with a slight blast in the producers, a clean gas is made, which will not clog the small burners. The character of the sponge—its state of proper deoxidation—is very easily and certainly determined by its lustre, color, and feeling, and especially by its appearance and softness when cut with a knife.

The carbon charged in with the coal may be either coke, anthracite, or charcoal. It should be crushed, so that its coarsest pieces will pass an inch mesh screen, and the ore should pass a 1½ inch screen.

There is apparently no limit, perhaps within blast furnace dimensions, to the size of the reducing cylinder. The first one that made sponge on a commercial scale was 11 in. by 13 ft. Two successively larger sizes were then employed with constantly improved results; and the present furnace (4½ ft. by 42 ft.) is easier to manage and much cheaper per ton of product than the smaller ones.

The cost of sponge, as determined from over three years' commercial practice, averages about £1 less per ton of iron in the sponge, than pig iron made from the same ores. All ores of moderate richness (not necessarily very rich ores) that are pure enough to make the commoner sorts of Bessemer pig, are certain to make a most excellent sponge. Mr. Blair has made a number of satisfactory experiments with lean ores, and also with ores containing that

class of impurities which will leave the sponge just as silica will when the sponge is fused in a Siemens-Martin bath; for instance, ores containing phosphorus combined with lime; but as these are not yet matters of every-day practice we will not follow them further at present.

The best method of utilizing sponge, in the present state of the art, is to substitute it for wrought-iron in the Siemens-Martin, or open hearth process. No new apparatus or treatment of any sort are required in this part of the operation. The cold sponge is simply thrown into the pig-iron bath; it instantly disappears under the slag; it is, from its porosity, rapidly melted; its silica and all its earthy impurities rise to the surface, and the iron remains. The amount of slag is somewhat larger than where wrought-iron is used, but if a lean ore is employed the excess of slag is tapped off. The first time this sponge was ever used in an open hearth furnace, it was charged in the proportion of three quarters sponge to one quarter Bessemer pig, with the usual spiegel; and the product was excellent boiler plate, and was sold as such. The waste was almost exactly the same as with charcoal blooms.

In the early practice it was thought necessary to compress the sponge, cold, into blooms of about one-third the density of iron; but this process is now only employed with the very fine sponge; the coarse gives equally good results when charged in its loose state.

The advantages of sponge in the Siemens-Martin steel manufacture is obviously these: First, the material is better than that obtained from the same ore by any indirect method. No ore is reduced except the ore of iron. For instance, the silica is not reduced to silicon, but is simply baked sand, which subsequently floats off in the bath; and thus one principal bane of fine steel is dispensed with. The same is true of most of the other impurities It is not true, however, of sulphur and of phosphorus when combined with the iron in the ore.

Second, the sponge is cheaper than any material that can be obtained from the ore by any indirect method. The use of raw ore in the Seimens-Martin process is by no means an equivalent. Only enough raw ore can be used to make up the loss—to restore the iron oxidized in the process. The other material put into the bath is less pure than sponge, and costs, on the average, more than pig-iron, while sponge costs less.

Mr. Blair has made some very encouraging trials in welding sponge, also in carburizing it, so as to use it in the open-hearth furnace without admixture of pig-iron; but as these are details not yet fully worked out, we will pospone their consideration.

TECHNICAL EDUCATION.

Written for Van Nostrand's Eclectic Magazine.

While technical and scientific schools are multiplying themselves all over the country, and sending forth every year a graduated class of young men, aspirants for positions as civil engineers, it may not be inappropriate to inquire how far the instruction afforded by such institutions is calculated to benefit and advance its recipients, and, more particularly, how far it is indispensable to success in the career of civil engineer.

In other professions, the evidence is clearer. It is so well known as a practical fact, that no man can possibly be a doctor or a lawyer without devoting many years to hard book-work, that taking a degree, *i. e.*, obtaining a certificate that this work has been satisfactorily performed, is necessary to enable one to practice either as doctor or lawyer.

In engineering the case is different. In the face of the many admirable works which we see every day planned and executed by "practical men," *i. e.*, men who owe but little to any school save that of observation and precedent, it would be hard to say what, if any, special education was indispensable to an engineer. Moreover, we venture the assertion, which we feel confident no engineer will undertake to challenge, that in one very important branch of the profession, that of railroad engineering, success depends upon conditions wholly disconnected from books and schools. In other words, a man after passing through a four years' course of laborious study, may

enter a railroad corps, spend his life in railroad engineering, rise to the chief engineership of the most important line in the country, and during all that time never have occasion to recall one single item of the instruction of his four years' course.

Undoubtedly, in running the transit (and at this exhilarating exercise he will probably pass an apprenticeship of several years) he must know enough of the plainest of plane trigonometry to be able to work around an obstructive schoolhouse and get back to his line again, and to find his way to any ground indicated by the assistant engineer; but all this, and the like, only requires that amount of mathematical knowledge usually taught in seminaries for young ladies, and if he has not already acquired it he can readily pick it up as he goes along.

If, on the other hand, our student gets into construction, he will find throughout that scientific knowledge waits upon practical experience; and if he is wise, for one scientific counsel that he takes from his text books, he will take twenty practical ones from the foreman of the works. After calculating the dimensions of his battering retaining wall, he had a great deal better submit his design to the boss mason than to the faculty of his engineering school.

The great difficulty in reducing engineering to a written science, so as to admit of its being learned from books, is the determination of data. The elements which force themselves in practice into the problem are so manifold and perplexing as to baffle the attempt to catalogue them; but their existence is *felt* by the practical man, and a faculty which is to obscure questions of construction what conscience is to moral ones, whispers to him the proper course to pursue, where engineering ethics would altogether fail him.

Not only is it difficult to specify all the data entering into engineering problems, but it is still more difficult to recognize them when encountered in practice. For instance, in the matter of foundations, the student may be taught that a certain system of founding is applicable to cases where the natural soil is capable of sustaining the weight of the intended superstructure, while a different plan is to be followed when it is not. Fancy the hopeless condition of the young gentleman *ætat.* 21, graduated A1 from a crack technological school, brought face to face with the "natural soil," and obliged to decide, from the light shed on the subject by his books, what kind of foundation he should put in! Of course it is true of all professions that a certain amount of practical experience is necessary to enable one to wield his theoretical knowledge, but it is so largely true of engineering that it would seem in some cases that the theoretical part was completely thrown out of the record, and as if any attempt to recall rules and figures would simply impede the only true guides; *i. e.*, practical judgment and artistic intuition.

What, then, are the advantages of a technical education to the engineer? In spite of what we have written above, we take them to be very great indeed, far greater, in fact, than can appear from any short-sighted utilitarian view of them. All that we have said involves no paradox, but simply proves that, as yet, engineering is an art rather than a science, and as such gains more from individual qualities, supplemented by individual experience, than from the application of established rules that may be taught and learned, and which are as effective in the hands of a comparative dunce as in those of a man of transcendent genius. Of the laws governing the forces with which in engineering we have to deal, we can claim but an imperfect knowledge. Still, these laws do exist, and every successful effort to recognize them and reduce their action to an equation, raises the art of engineering, by so much, from a mere trade, governed by empirical maxims, toward the dignity of a liberal profession.

In the effort to make engineering an exact science, practical difficulties, *i. e.*, elements neglected in the theoretical calculation, but none the less potential in practice, will of course encumber our path; but these elements are being constantly detected and noted, and added to the specification, making our data constantly more and more complete. Everything connected with engineering construction is susceptible of mathematical calculation—and usually a very simple calculation—when we are sure that we have all the elements coming into play, and one of the objects of a technical education is to give the student such command of the resources of mathematical investigation as to enable him to figure out, with confidence in his results, any new problem presented to him.

The great mistake committed by the graduates of our technical schools is in

supposing that because they have in their pocket the degree of civil engineer, that they are therefore, actually and truly, engineers. No mistake could be more fatal. A freshly graduated medical student might as well think he was a doctor; and with greater reason, in fact, for he at least has seen a good deal of *genuine work* in the hospitals, done by the most eminent members of his profession. It is quite natural, certainly, that a young man who has sedulously devoted himself to years of patient, special study, should consider that at the end of that time he was qualified to practice what he had been so long learning; but he should recollect that all this was preparatory work, and that on leaving his school he was just ready to begin learning his profession. Whenever this fact is realized, and the student commences earnestly to work at his profession after graduating, he will find his preparatory education of inestimable advantage to him; whenever it is ignored, and the student imagines that his studies have placed him beyond the need of further work, and above all merely practical men, he will find that instead of an aid, they are the worst clog he could have placed upon his future. He may be a pedant, but never an engineer.

USE OF TIMBER IN CONNECTION WITH MECHANICAL WORK.

From "Iron."

At the meeting of the Manchester Scientific and Mechanical Society, briefly noticed last week, Mr. J. G. Tynde, C. E., borough surveyor, Manchester, during the course of his presidential address, dwelt at some length on the use of timber in connection with mechanical work, both with regard to pattern-making and in relation to the erection and removal of heavy machinery.

The proper selection and use of timber, he said, was a matter in which they were all more or less interested, and he would offer a few observations on the subject, based on his own experience. For all ordinary purposes the kind of timber most used for pattern-making, and in temporary structures, such as travelling cranes, staging framework, and platforms for the erection of bridges and similar work, was fir, either American or Baltic, the nature and properties of the different descriptions of which, as usually met with in our market, he proposed shortly to describe ; but before doing so it might be interesting if he gave a very slight sketch of its introduction to this country. Previously to the colonization of America our supply of fir timber was obtained from the countries on the coasts of the Baltic, of which Norway, Russia and Sweden were the first resorted to. The colonization of America, however, soon opened a large and valuable field for obtaining timber of similar growth, the two Canadas especially yielding large supplies of a very fine quality. More recently a supply of the same kind of timber had been obtained from Savannah and the adjacent States of America, and efforts were now being made to open a trade with California, where was to be found some of the finest red wood ever brought into our market. Fir timber might be divided into three distinct classes, known by the color of their wood—by white, yellow and red. American spruce deals belonged to the first-named class, and were principally used for joists and bearing timbers in common houses as well as for scaffolding in the erection of machinery. There was so much of a very inferior quality of this kind of timber that it was necessary a very practical knowledge of it should be acquired by those under whose directions it was used, as serious accidents frequently happened when it was misapplied. Baltic white deals were wood of a very fine texture, and used principally for the same purposes as the American spruce deals. This timber would not, as a rule, bear so great a load as the American, but it was much less liable to warp from change of temperature. Both these kinds of timber were specially liable to decay if placed in warm and moist situations, fungi speedily forming on them, and causing what was commonly known as dry-rot; and when once this had been commenced, the wood was no longer to be depended upon. These woods were both extensively used for packing-cases for machinery, and for this purpose were quite as good as more expensive timber. The next class of timber to which he would direct their attention was the American yellow pine. This timber was

imported in logs, and cut up into boards or scantlings in this country; like the white wood, this timber was practically non-resinous; it was of a fair texture, and when not exposed to damp was durable. It was much used for building purposes, especially for joiners' work that was covered with paint. As a bearing timber it had a peculiar quality—viz., that it retained its form with a permanent load; whereas many kinds of timber when loaded continued to deflect for years, although the load might not be greater than they might safely be required to bear. Unless, however, this wood was properly treated from the log, its valuable quality of retaining its form was materially impaired. The log should be opened and cut into boards in the autumn, and exposed to the weather through the winter; in the spring it should be removed into the drying shed, and thence into a room having a corresponding temperature with that wherein it was to be stored when finished, for at least one month before being worked. On no account should this wood be placed in a stove, as in its removal from a high temperature it would always be liable to change its form. There were many qualities of yellow pine, and their quality varied very considerably. Next, referring to the red wood, he said this timber was imported both from America and the Baltic in the form of both logs and deals. There were several varieties of red deals, each possessing its own peculiar character; but all of them more or less valuable on account of their power to resist atmospheric changes and the action of moisture. It was, therefore, much used in engineering works for piles and timber framing exposed to the weather, railway sleepers, and all places where it was necessarily shut out from a free passage of air. It was also less liable than any other kind to dry-rot. The timber imported from Sweden was generally of a very inferior quality and of small size; it was very liable to crack if exposed to the sun, causing what were known as "sun-strokes." The custom at all the ports on the arrival of the timber was to put the logs into water to prevent this. The pitch-pine imported from the Southern States of North America, Savannah, and Pensacola, was of a strongly resinous character, but had a great tendency to dry-rot, especially if it was placed in contact with fresh mortar and lime. This timber was, therefore, unfit to be built into walls as bearing beams, unless the ends were placed in cast-iron boxes, or were otherwise protected so as to allow a free circulation of air round the ends of the beams. Many samples of this timber had a beautifully waved grain, and would take a high polish, and these were selected and used for ornamental joiners' work. One peculiarity in connection with all red-wood was, the varied qualities found in the same log; the lower part of a tree might be exceedingly good, while the upper part might be very inferior. From the remarks he had made, it would be seen how impossible it was to fix any arbitrary formula that would be applicable for calculating its strength, the quality being so variable the same formula would not apply in any two cases. He had tried some experiments on a sufficiently large scale to guide his own judgment, and he found that for a very good and selected sample of Baltic timber the following simple formula for beams might be relied upon:—the breaking weight in the centre equalled the product of the breadth with the square of the depth multiplied by .15, and divided by the length in feet; and for an ordinary sample of timber he usually took the safe load in the centre in tons equal to the product of the breadth, with the square of the depth multiplied by .03, and divided by the length in feet.

The President then brought his remarks to a close, with the expression of the hope that the subject would be again referred to, and other descriptions of timber dealt with.

PRODUCTION OF PIG IRON IN THE UNITED STATES IN 1872 AND 1873.

From "The Bulletin."

We present herewith full and accurate statistics of the production of pig iron in the United States in 1872 and 1873, derived from returns made directly to the office of the American Iron and Steel Association by the makers and by the regular correspondents of the Association. This exhibit is the most complete of the kind

that has ever been given to the country, and its preparation alone has cost the Association thousands of dollars. We briefly summarize the leading facts set forth in the detailed statements which follow, premising them by remarking that our tables do not include abandoned furnaces:

Whole No. of stacks December 31, 1871	571
Whole No. of stacks built in 1872	41
Whole No. of stacks December 31, 1872	612
Whole No. of stacks built in 1873	50
Whole No. of stacks December 31, 1873	662
Whole No. of stacks in blast Jan. 1, 1874	410
Whole No. of stacks out of blast Jan. 1, 1874	252
Whole No. of stacks completed in first 6 months of 1874	11
Whole No. of finished stacks, July 1, 1874	673
Whole No. of stacks building July 1, 1874	53
Whole No. of stacks projected, July 1, 1874	61
Total production in 1872, tons of 2,000 lbs.	2,854,558
Total production in 1873, tons of 2,000 lbs.	2,868,278
Estimated annual capacity of all finished stacks, net tons	4,500,000
No. of States having furnaces	22
No. of States making pig iron in 1872	25
No. of States making pig iron in 1873	21

PRODUCTION OF PIG IRON IN 1872 AND 1873 BY STATES.

STATES.	No. of stacks in blast Jan. 1, 1874.	No. of stacks built in 1872.	No. of stacks built in 18	Whole No. of stacks in 1872.	Whole No. of stacks in 18 3.	Whole No. of stacks July 1, 1874.	No. of stacks building in 1874.	No. of stacks projected in 1874.	Make in 1872—Tons of 2,000 lbs.	Make in 1873—Tons of 2,000 lbs.
Maine	1	....	....	1	1	1	....	....	.....	780
Vermont	1	....	....	2	2	2	....	....	2,000	3,100
Massachusetts	5	....	....	6	6	6	....	....	17,070	21,13
Connecticut	8	....	....	10	10	10	....	....	22,700	26,977
New York	43	2	4	49	53	53	4	3	291,155	296,818
New Jersey	6	2	1	12	13	13	4	1	103,858	102,341
Pennsylvania	166	19	14	248	262	263	18	16	1,401,497	1,389,573
Maryland	17	....	....	22	22	23	....	2	63,031	55,986
Virginia	13	2	3	32	35	36	4	1	21.445	26,475
North Carolina	3	....	1	7	8	8	1	2	1,073	1,432
South Carolina	....	....	....	8	8	8	....	....	...	.....
Georgia	6	....	2	6	8	9	3	1	2,945	7,501
Alabama	7	....	3	8	11	12	4	3	12,512	22,283
Texas	...	....	...	1	1	2	....	....	619	280
West Virginia	5	1	1	5	6	6	3	3	20,796	23.056
Kentucky	16	....	....	25	25	27	....	2	67,396	69,889
Tennessee	11	1	1	19	20	20	2	7	42,454	43,134
Ohio	65	6	5	83	88	88	8	9	399,743	406,029
Indiana	....	2	....	8	8	8	....	....	39,221	32.486
Illinois	1	....	2	8	10	10	2	....	78.627	55,796
Michigan	19	4	6	27	33	34	....	6	100,222	123,506
Wisconsin	7	1	3	10	13	14	....	....	65,036	74,148
Minnesota	....	....	...	....	....	1	....	....	....	.....
Missouri	10	1	4	14	18	18	....	5	101,158	85,552
Oregon	....	....	....	2	1	1	....	....	.....	.....
Total	410	41	50	612	662	673	53	61	2,854,558	2,868,278

Pennsylvania, with 262 stacks, makes very nearly one-half the pig iron made in the country. Ohio comes next, making one-seventh of the whole product with 88 stacks. New York, with 53 stacks, makes over one-tenth of the whole product. These three States and New Jersey make more than three fourths of the total product. Five Western "prairie" States, Indiana, Illinois, Michigan, Wisconsin, and Missouri, made 13½ per cent. of all the pig iron produced in 1872, and 12½ per cent. of all made in 1873. It is a singular fact that South Carolina has eight charcoal furnaces, and that not one of them was in blast in 1872 or 1873. The lack of capital to operate them, and the need of repairs, are assigned as the reasons for their long

suspension. Fuel and ore of an excellent quality are abundant in their vicinity, and it is scarcely possible that they will all remain much longer out of blast. Two other Southern States, Alabama and Georgia, are making rapid progress in the manufacture of pig iron, for which they possess truly wonderful facilities.

Charcoal.

States.	No of stacks in blast Jan. 1, 1874.	No. of stacks built in 1872.	No. of stacks built in 1873.	Whole No. of stacks in 1872.	Whole No. of stacks in 1873.	Whole No. of stacks July 1, 1874.	No. of stacks building in 1874.	No. of stacks projected in 1874.	Make in 1872—Tons of 2,000 lbs.	Make in 1873—Tons of 2,000 lbs.
Maine	1	....	....	1	1	1	....	....	.....	780
Vermont	1	....	....	2	2	2	....	....	2,000	3,100
Massachusetts	4	....	....	5	5	5	....	....	12,820	15,704
Connecticut	8	....	....	10	10	10	....	....	22,700	26,977
New York	14	1	2	15	17	17	...	....	19,812	29,329
Pennsylvania	28	....	1	38	39	39	....	....	45,033	45,854
Maryland	12	....	....	14	14	14	....	....	29,044	30,315
Virginia	11	2	2	30	32	33	2	1	21,445	20,075
North Carolina	3	....	1	7	8	8	1	1	1,073	1,432
South Carolina	....	....	....	8	8	8	....	....	.....	.....
Georgia	6	....	2	6	8	9	3	1	2,945	7,501
Alabama	7	....	3	8	11	12	4	3	12,512	22,283
Texas	....	....	....	1	1	2	....	....	619	280
West Virginia	3	....	1	3	4	4	....	....	950	1,950
Kentucky	14	....	....	22	22	23	....	2	39,699	42,219
Tennessee	10	....	....	17	17	17	....	3	34,094	34,532
Ohio — Hanging Rock	33	....	....	33	33	33	....	....	87,440	92,365
Ohio — Miscellaneous	2	....	....	4	4	4	....	....	8,182	8,133
Ohio — Total	35	....	....	37	37	37	....	....	95,622	100,498
Michigan	18	2	6	22	28	29	....	6	86,616	113,475
Wisconsin	6	1	2	8	10	11	....	....	27,790	38,880
Minnesota	....	....	....	....	....	1	....	....	.....	.....
Missouri	8	....	2	7	9	9	....	2	45,589	39,536
Oregon	....	....	....	1	1	1	....	....	.....	.....
Total	189	6	22	262	284	292	10	19	500,363	574,720

The production of charcoal pig iron increased nearly 75,000 tons in 1873 over the product of 1872, while there was a decrease in the production of both bituminous and anthracite pig iron. In each year named the quantity of anthracite pig iron produced was nearly one-half of the total product. The average annual product of the furnaces of the country, in net tons, is as follows: charcoal, 2,024 tons; bituminous coal and coke, 5,592 tons; anthracite, 6,435 tons.

There never having been any record kept of the quantity of pig iron on hand and unsold in this country, from year to year, it is obviously impossible to ascertain accurately the consumption of pig iron in any given year, but a very close approximation can be made by adding the production in that year to the quantity imported. Observing this method, we have the following results for 1872 and 1873:

Home production of pig iron in 1872, net tons.	2,854,558
Pig iron imported in 1872, net tons	295,967
Total consumption of pig iron in 1872, net tons	3,150,525
Home production of pig iron in 1873, "	2,868,278
Pig iron imported in 1873, "	154,780
Total consumption of pig iron in 1873, "	3,023,058

In 1872 and 1873 our exports of pig iron to all countries (principally to Canada) were as follows: In 1872, 26,380 cwts.; in 1873, 180,436 cwts. A year ago much was

said in public journals of alleged shipments of pig and bar iron to Great Britain, but the most diligent inquiry fails to show that such shipments were ever made, although, as has heretofore been remarked, it is not improbable that English and Scotch founders will yet require large quantities of our charcoal iron for car-wheel purposes. This want, however, will not be created until the American method of making car-wheels becomes more popular in Great Britain than it now is. The British car-wheel, as at present constructed, is not composed, in whole or in part, of charcoal pig iron.

Bituminous Coal and Coke.

States.	No. of stacks in blast Jan. 1, 1874.	No. of stacks built in 1872.	No. of stacks built in 1873.	Whole No. of stacks in 1872.	Whole No. of stacks in 1873.	Whole No. of stacks July 1, 1874.	No. of stacks building in 1874.	No. of stacks projected in 1874.	Make in 1872—Tons of 2,000 lbs.	Made in 1873—Tons of 2,000 lbs.
Penn. Shenango Valley	15	5	2	29	31	31	2	1	160,188	160,831
Penn. Allegheny County	11	4	....	11	11	11	1	1	110,599	158,789
Penn. Miscellaneous	18	....	1	31	32	32	3	2	117,224	111,104
Penn. Total	44	9	3	71	74	74	6	4	388,011	430,634
Maryland	1	....	....	4	4	4	....	2	12,079	5,264
Virginia	....	....	....	....	....	....	1	....	.....	.....
North Carolina	....	....	....	....	....	....	....	1	.....	.....
West Virginia	2	1	....	2	2	2	3	3	19,846	21,106
Kentucky	2	....	....	3	3	4	....	....	27,697	27,670
Tennessee	1	1	1	2	3	3	2	4	8,360	8,602
Ohio. Hanging Rock	5	1	1	6	7	7	5	2	23,169	28,601
Ohio. Mahoning Valley	14	2	1	27	28	28	....	....	200,785	157,888
Ohio. Miscellaneous	11	3	3	13	16	16	3	7	80,167	119,042
Ohio. Total	30	6	5	46	51	51	8	9	304,121	305,531
Indiana	....	2	....	8	8	8	....	....	39,221	32,486
Illinois	1	....	2	8	10	10	2	...	78,627	55,796
Michigan	....	....	....	3	3	3	....	....	13,382	795
Missouri	2	1	2	7	9	9	....	3	55,569	46,016
Total	83	20	13	154	167	168	22	26	946,913	933,900

Anthracite.

Massachusetts	1	....	....	1	1	1	....	....	4,250	5,432
New York	29	1	2	34	36	36	4	3	271,343	267,489
New Jersey	6	2	1	12	13	13	4	1	103,858	102,341
Penn. Lehigh	30	3	3	44	47	47	6	....	449,663	389,969
Penn. Schuylkill	26	3	3	37	40	41	4	4	232,225	236,409
Penn. U. Susqueh'na	14	3	....	25	25	25	1	4	127,260	129,304
Penn. L. Susqueh'na	24	1	4	33	37	37	1	4	159,305	157,403
Penn. Total	94	10	10	139	149	150	12	12	968 453	913,085
Maryland	4	....	....	4	4	5	....	....	21,908	20,407
Virginia	1	....	....	1	1	1	....	....	.....	4,000
Total	135	13	13	191	204	206	20	16	1,369,812	1,312,754

Anthracite Coal and Coke.

States.	No. of stacks in blast Jan. 1, 1874.	No. of stacks built in 1872.	No. of stacks built in 1873.	Whole No. of stacks in 1872.	Whole No. of stacks in 1873.	Whole No. of stacks July 1, 1874.	No. of stacks building in 1874.	No. of stacks projected in 1874.	Make in 1872—Tons of 2,000 lbs.	Make in 1873—Tons of 2,000 lbs.
Wisconsin	1	....	1	2	3	3	....	....	37,246	35,268
Michigan	1	1	....	1	1	1	....	....	.....	8,736
Total	2	1	1	3	4	4	....	....	37,246	44,004

Peat and Charcoal.

Michigan	..	1	..	1	1	1	..	..	224	500

Charcoal and Bituminous Coal.

Virginia	1	..	1	1	2	2	1	..	.....	2,400

RECAPITULATION.

	No. of stacks in blast Jan. 1, 1874.	No. of stacks built in 1872.	No. of stacks built in 1873.	Whole No. of stacks in 1872.	Whole No. of stacks in 1873.	Whole No. of stacks July 1, 1874.	No. of stacks building in 1874.	No. of stacks projected in 1874.	Make in 1872—Tons of 2,000 lbs.	Make in 1873—Tons of 2,000 lbs.
Charcoal	189	6	22	262	284	292	10	19	500,363	574,720
Bituminous Coal and Coke	83	20	13	154	167	168	22	26	946,913	933,900
Anthracite	135	13	13	191	204	206	20	16	1,369,812	1,312,754
Anthracite Coal and Coke	2	1	1	3	4	4	....	....	37,246	44,004
Peat and Charcoal	....	1	....	1	1	1	....	....	224	500
Charcoal and Bituminous Coal	1	....	1	1	2	2	1	....	.....	2,400
Total	410	41	50	612	662	673	53	61	2,854,558	2,868,278

Appended is a table showing the production of the various kinds of pig iron in the United States from 1854 to 1873, both years inclusive. It is compiled from statistics procured by this Association. Prior to 1854 no agency existed for the collection of the statistics of the iron trade, but in 1855 this Association was organized, and since then it has regularly collected and published these statistics. All that is definitely known of the progress of the iron industry in this country prior to 1854 is embraced in

a statement prepared by the Hon. Henry C. Carey, in 1849, and this statement we also append:

Production of Pig Iron from 1854 *to* 1873.

Years.	Anthracite.	Charcoal	Bituminous Coal & Coke.	Total.
1854..	339,435	342,298	54,485	786,218
1855.	381,866	339,922	62,390	784,178
1856..	443,113	370,470	69,554	883,137
1857..	390,385	330,321	77,451	798,157
1858.	361,430	285,313	58,351	705,094
1859..	471,745	284,041	84,841	840,627
1860	519,211	278,331	122,228	919,770
1861..	409,229	195,278	127,037	731,544
1862..	470,315	186,660	130,687	787,662
1863..	577,638	212,005	157,961	947,604
1864..	684,018	241,853	210,125	1,135,996
1865..	479,558	262,342	189,682	931,582
1866	749,367	332,580	268,396	1,350,343
1867	798,638	344,341	318,647	1,461,626
1868..	893,000	370,000	340,000	1,603,000
1869..	971,150	392,150	553,341	1,916,641
1870..	930,000	365,000	570,000	1,865,000
1871..	956,608	385,000	570,000	1,912,608
1872	1,369,812	*500,587	†984,159	2,854,558
1873..	1,312,754	‡577,620	§977,904	2,868,278

* Includes 224 tons of peat pig iron.

† Includes 37,246 tons of mixed anthracite and coke pig iron.

‡ Includes 500 tons of mixed peat and charcoal pig iron, and 2,400 tons of mixed charcoal and bituminous coal pig iron.

§ Includes 44,004 tons of mixed anthracite and coke pig iron.

Mr. Carey's Pig Iron Statistics.

In 1810 the whole number of furnaces in the Union was 153, yielding 54,000 tons of metal, equal to 16 lbs. per head of the population.

In 1821 the manufacture was in a state of ruin.

In 1828 the product had reached 130,000 tons, having little more than doubled in 18 years.

In 1829 it was 142,000 tons. Increase in one year, nearly ten per cent.

In 1830 it was 165,000 Increase in two years, more than 25 per cent.

In 1831 it was 191,000. Increase in three years, about 50 per cent.

In 1832 it was 200,000, giving an increase in three years of above 60 per cent.

In 1840 the quantity given by the census was 286,000, but a committee of the Home League, in New York, made it 347,700 tons Taking the medium of the two, it would give about 315,000 tons, being an increase in 8 years of 50 per cent.

In 1842 a large portion of the furnaces were closed and the product had fallen to probably little more than 200,000, but certainly less than 230,000 tons.

In 1846 it was estimated, by the Secretary of the Treasury, at 765,000 tons, having trebled in four years.

In 1847 it was supposed to have reached the amount of not less than 800.000 tons.

In 1848 it became stationary.

In 1849 many furnaces being already closed, the production of the present year cannot be estimated above 650,000 tons; but from the accumulation of stock and the difficulty of selling it, it is obvious that the diminution will be greater.

In the 20 years ended with 1873, the growth of the pig iron industry of the United States, as compared with that of the United Kingdom of Great Britain, was as follows. The ton used in the statistics of the United Kingdom is the gross ton of 2,240 lbs.; that used in the statistics of the United States is the net ton of 2,000 lbs.

Year.	U. King. Tons.	U. States Tons.
1854	3,069,838	736,218
1855	3,218,151	784,178
1856	3,586,377	883,137
1857	3,659,477	798,157
1858	3,456,064	705,094
1859	3,712,904	840,627
1860	3,826,752	919,770
1861	3,712,390	731,544
1862	3,943,469	787,662
1863	4,510,040	947,604
1864	4,767,901	1,135,996
1865	4,819,254	931,582
1866	4,523,897	1,350,343
1867	4,761,023	1,461,626
1868	4,970,206	1,603,000
1869	5,445,757	1,916,641
1870	5,963,515	1,865 000
1871	5,627,179	1,912,608
1872	6,741,929	2,854,558
1873	6,850,000	2,868,278

The value of the pig iron product for any year can be approximately ascertained by multiplying the average market value throughout the year of each kind of iron by the year's product, and adding the results thus obtained. In this manner we have carefully calculated the value of the pig iron manufactured in this country during the years 1872 and 1873, and find it to be as follows:

Value of 2,854,558 net tons of pig iron produced in 1872 ..... $132,649,621

Value of 2,868.278 net tons of pig iron produced in 1873... 118,243,308

In 1854 the production of anthracite pig iron overtook that of charcoal, and in 1869 the production of charcoal pig iron was again overtaken by that of bituminous coal and coke. Since 1854 anthracite has been the leading branch of our pig iron industry, and since 1869 charcoal has been the least productive of all branches.

THE old iron mine in Salisbury, Ct., which has been worked over one hundred and fifty years, recently declared an annual dividend of one hundred and fifteen per cent.

THE CHANNEL TUNNEL.

From "Nature."

We fear there are still many who fail to see that any good can come of scientific research unless it has some well-defined "utilitarian" object in view. Even in this and in other countries that are in the van of civilization, and in which education is comparatively wide-spread, the majority of mankind can appreciate a benefit only when it takes a concrete and tangible form. That love of knowledge for its own sake, that noble inquisitiveness which has been so fruitful in results during the last two hundred years, even yet belongs to comparatively few, who are still regarded by the many with a kind of impatient pity as mere unpractical hobby-riders. Still the people who talk in this way are proud enough of the glory which their great men have shed upon their country, and would not willingly, we believe, part with it for money, were this possible; and, indeed, how would this country appear among the nations, were she deprived of the inestimable inheritance which her great sons have bequeathed to her in every department of intellectual activity? Happily, however, the race of those who decry single-eyed scientific research is getting sensibly smaller; and we firmly believe that as education improves, and as higher education spreads, carrying with it the results of this same scientific research, it will disappear.

Still, a little consideration might show those who are ever ready to cry "what's the good?" that since all so-called "practical" schemes are concerned either with man's own body or with the surrounding universe, an essential part of the basis of any scheme is a thorough knowledge of the material on which it is proposed to work. Such a knowledge it has over and over again been shown, is only to be attained by abstract scientific research, by investigation conducted as if the only end in view were a thorough knowledge of the subject in hand, in all its scientific aspects and relations. Many instances could be given, and indeed are every day occurring, of the highest practical results unwittingly following from such investigations; and to the skeptic we could not recommend a better example of how indispensable is thorough scientific research as a basis for the useful arts than the results of the investigation into the geology of the Channel, which Mr. Prestwich (the newly elected Oxford Professor of Geology) presented to the Institution of Civil Engineers last December, and which, with the subsequent discussion and maps, has just been published in a separate form. This study of the strata which underlie the Channel, and which seems to us an almost perfect example of close and careful reasoning on physical facts, is now brought forward to enlighten the projectors of a tunnel between England and France as to the nature of the material with which they will have to work; but Mr. Prestwich distinctly states that the various formations are considered "irrespective of their relative merits in any other than a geological point of view."

Mr. Prestwich's plan is to discuss carefully all the strata which underlie the Channel, from the London clay down to the Palæozoic series, exhibiting distinctly their lithological characters, dimensions, range and probable depth, and from these data deducing his conclusions as to the suitability of each formation for being pierced by a tunnel. The investigations of himself and others, on which Mr. Prestwich's paper is founded, were mostly undertaken from no practical point of view, and before a Channel Tunnel was thought of. Mr. Prestwich, many will be glad to think—grateful, we hope at the same time, for this very practical result of pure scientific research—concludes that from a geological point of view it is quite practicable to construct a tunnel underneath the Channel, although to do so with safety it will be necessary to go very deep down. But an excellent idea of the results of the investigation will be obtained from the following clear summary with which Mr. Prestwich's paper concludes:

"In the London clay there exists a perfectly impermeable bed of sufficient thickness, but nowhere between the two countries, except probably at points where the distance presents apparently insuperable difficulties. The lower chalk, or chalk marl, affords a comparatively impermeable deposit, also of sufficient dimensions; but from its having a calcareous base, and from the possibility of fissures, with the absence

of a protecting overlie, it has great uncertainty. In the gault there is another impermeable stratum, but of dimensions too small. The lower green-sand contains no beds sufficiently continuous and impermeable. The Weald clay ranges about halfway across the Channel; and if a belt of it should possibly pass round at the north end of the Varne and range to Wissant, it might prove to be worth further inquiries. In the Kimmeridge clay there is again a deposit of sufficient dimensions, but with a subordinate band which may be sufficiently permeable to present difficulties, while, though it comes to the surface on the French coast, its depth on the English coast must be very considerable. There is, however, just a chance that the Kimmeridge clay may in mid-channel be overlapped unconformably, and at a slight angle, by the Weald clay, and in that case they might for all purposes be considered as continuous strata. The Oxford clay presents similar difficulties, in addition to its greater depth and inaccessibility. In the secondary strata, the irregular lie of the strata, and the presence of faults, are contingencies important to be considered.

"On the other hand, the great mass of the Palæozoic rocks, so protected by impermeable overlaying strata, is of such great dimensions, and so compact, and holds its range so independently of the more irregular range of the secondary strata, that it offers the conditions most favorable for the secure construction of a submarine tunnel; and that such strata can be worked in safety, and for considerable distances under great bodies of water, has been proved at Whitehaven and Mons. But, on the other hand, the depths of these old rocks below the surface is very great, and they are much more dense and harder than the overlying formations.

"There is another important problem in connection with the Palæozoic rocks which such an undertaking might help to solve. The great question of the range of the coal measures under the south of England has lately come prominently into notice; and it was, in fact, in inquiries connected with that question that the foregoing considerations presented themselves to the author. The rich coal basin of Mons and the north of France has been traced to within 30 miles of Calais, where it thins out; but, like the coal basins of Liege, Aix and Westphalia, which form separate sections of the same great trough, to the eastward, so there is reason to suppose that other sections of the trough set in on the westward, forming other coal basins, which possibly range to the west of England (Somersetshire), passing under the north-eastern part of Kent and the Thames. Any such work, therefore, as a submarine tunnel in these Palæozoic rocks could not fail to throw much light on the subject; while, in case it were to hit upon the line of strike of the coal measures, and could be carried on along that line, the work might prove otherwise remunerative, and tend to solve the great problem which interests so largely both geologists and the general public.

"Such, briefly, are the conditions which bear on the construction of a submarine tunnel between France and England. The author is satisfied that, considered on geological grounds alone it is in one case perfectly practicable, and in one or two others it is possibly so; but there are other considerations besides those of a geological nature, and whether or not they admit of so favorable a solution is questionable. In any case the author would suggest that, the one favorable solution admitted, it may be desirable, in a question involving so many and so great interests, not to accept an adverse verdict without giving to all those other considerations the attention and deliberation which the importance of the subject deserves.

"Under any circumstances, the difficulties are formidable. Whether or not they are insuperable are questions which may safely be left to civil engineers. The many and great obstacles overcome by engineering science in late years lead the author to expect that, should the occasion arise, and the attempt be considered worth the cost, the ability to carry it out would not be wanting. Various preliminary trials are, however, indispensable, in order to clear up some of the geological questions, before a balance of the comparative advantages presented by the different formations could be satisfactorily settled, and before the grounds for action could be accepted."

From this it will be seen that the possibility of a Channel Tunnel remains now only with the engineers to decide. Geology has told them all the natural conditions under which they will have to work, so far as these can be known without actually tunnelling; and since so cautious a reasoner as Mr. Prestwich thinks it possible to carry out the scheme from a geological

point of view, we should think that if it could be proved that the undertaking would pay, our engineers would be eager to show that the resources of their art are quite equal to its successful accomplishment.

REPORTS OF ENGINEERS' SOCIETES.

MANCHESTER STEAM USERS' ASSOCIATION—CONTEMPLATED BOILER EXPERIMENT.—From the chief engineer's report of this association, we learn that it is intended to carry out some experiments for the purpose chiefly of obtaining information as to the weakness in boilers due to the openings cut for manholes, etc. We cannot do better than reproduce Mr. Lavington Fletcher's programme :—

"Those at all conversant with the association's monthly reports must have observed how many boilers have given way through the weakening effect of the manhole on the cylindrical portion of the shell, a fact to which boiler makers do not seem to have attached sufficient importance, or at all events till very recently. Those manholes from which the explosions recorded have arisen, have been unguarded, but the question remains whether the mouth-pieces now adopted for strengthening them are sufficient for the high pressures coming into such general use, and also how safety may be attained without unnecessary expenditure. In a well-constructed boiler the flue tubes are so well armed against collapse, and the flat ends so well stayed, that the weakest part of the structure is the cylindrical shell, and if this be double riveted, then the weakest part of the whole boiler is the manhole or other similar opening. This is apparent on a consideration of the strains, and is very frequently exemplified practically on the application of the hydraulic test. On such occasions cast-iron manhole mouthpieces not infrequently give way, and the boilers sometimes rip open on the top in a longitudinal direction. In one case a steel boiler though strengthened with a wrought iron manhole mouthpiece rent on each side of its longitudinally. Boilers also exhibit distress at the base of the steam domes, and in some recent experiments made in America to test the strength of boilers by bursting them under steam pressure the boiler was found to give way at that part. The association has always been alive to this weakness, and has for many years induced its members when laying down new boilers, to dispense with steam domes altogether. Many boilers, however, have openings cut in them at the base of steam necks, which are very similar to manholes in size, but are not by any means equally strengthened. These necks are sometimes planted on the top of boilers as much as 7 feet in diameter, and worked up to 70 or 80 pounds. They are inherent also in the construction of the French or elephant boiler, and many others now introduced for working steam at high pressures. Such boilers are sometimes placed in the basement of very lofty buildings, so that in the event of an explosion the results would be most serious. It is thought, therefore, that no uncertainty should be allowed to exist as to the effect of these openings on tho strength of cylindrical boilers worked at high pressures, and therefore it is proposed to construct an experimental boiler for the purpose of testing these necks and manhole mouthpieces by hydraulic pressure carried up to the bursting point.

"In the first instance it was proposed to construct a small cylindrical egg-ended boiler, say 5 feet 6 inches in diameter, and to plant such necks and mouthpieces upon it as it was thought to be desirable to test. On further consideration of the subject, however, it appeared that the experiment would be of far greater value if extended to a Lancashire boiler of ordinary working proportions, though its length might be somewhat shorter. In this way the precise diameter adopted in everyday practice, and also the precise thickness of plate, could be tested as well as the actual patterns in use for manhole mouthpieces, etc., which would afford more direct, and thus more satisfactory conclusions. Further than this, the adoption of an experimental boiler of the Lancashire type would allow the opportunity at the same time of testing the strength of the furnace tubes both as regards collapse and elongation, as well as of testing the flat ends with their gussets and longitudinal stays, and also the cylindrical shell at the longitudinal seams of rivets. Such a test would be most complete, and, after the disastrous explosion at Blackburn, would, it is thought, be of considerable practical value.

"With this view it is proposed to construct a Lancashire boiler, having a length of 21 feet, a diameter in the shell of 7 feet, and in the furnace tubes of 2 feet 9 inches, the longitudinal seams being double riveted, the front end plate attached with an external angle iron and the back with an internal one, and both strengthened with substantial gussets and longitudinal bolt stays, the thickness of the plates seven-sixteenths in the cylindrical portion of the shell, three-eighths in the furnace tubes and ½ inch in the flat ends. The reason for the length of the boiler is as follows :—It is important that the belt of plating on which the manholes and necks to be operated upon are placed should be free from all bias, and therefore it is proposed to plant the manholes, etc., on the belt of plating midway between the two ends of the boiler, and further to allow a free belt on each side of this one, so that it may not in any way be strained or affected by the action of the gussets. This involves a length of three belts of plating, and as the gussets occupy two belts of plating at each end, that involves seven belts together, and as these are 3 feet wide, it makes up the length of 21 feet. This length may at first sight appear considerable, but it will add to the value of the experiment not only as regards the shell but also as regards the collapsing tendency of the flue tubes, while it would not materially increase the expense of the experiment.

"The general outline of the experiment it is proposed should be as follows :—In the first place plant on the top of the central belt of plating a wrought iron neck of such a thickness and diameter as is now met with in boilers under inspection, viz., from 15 to 16 inches in diameter, seven-sixteenths of an inch in thickness, and attached to the boiler by a single line of rivets, the neck being blanked up at the top with a cover. This being done the hydraulic pressure to be applied and carried on until the plate bursts. The pres-

sure to be increased steadily, and meanwhile the behavior of the boiler to be carefully watched and measured. The furnace tubes to be gauged internally in the direction of their diameter to see if any tendency to collapse is discernible, and also gauged longitudinally to see if any extension of the flanged seams takes place. The flat ends to be tested both with and without the longitudinal bolt stays and gauged under both conditions at a number of points, so that their behavior may be ascertained. The wrought iron neck or manhole mouthpiece, as the case may be, to be gauged longitudinally and transversely to see what change of form takes place under the strain put upon it by the shell, and further, to ascertain the strain put upon the plates around the opening, a number of parallel lines to be inscribed upon the plate in a longitudinal direction before the pressure is put on, when it is expected that they will curve or bulge outwards away from the manhole on the application of the test. The amount of curve will no doubt much depend on the character of the plates.

"When the first neck has burst it would then be replaced with such other necks and manhole mouthpieces as it was thought desirable to test, the belt of plating also being renewed as occasion might require. As it is proposed that the central belt of plating should be an external one, renewing one of the plates on this belt as often as was necessary would not be a matter of much difficulty.

"There are many other points to which it would be worth while to direct attention, which will suggest themselves on further consideration, but the above is just an outline for the consideration of the committee.'

NOTE.—At the meeting at which the report was read, the committee took into consideration the above proposition to construct an experimental boiler to be tested with water up to the bursting point, and resolved to carry it into operation at once.

THE ASSOCIATION OF MUNICIPAL AND SANITARY ENGINEERS AND SURVEYORS

The Annual Meeting of the Members of this Association was held in the Council Chambers, Birmingham, on Thursday, the 28th ult., and following days. The annual report showed that the progress of the Society during the past year had been most encouraging.

The President (Mr. Lewis Angell) then delivered his inaugural address. After congratulating those present upon the success which had attended their efforts to establish the Association, he said they had united the scattered members of a special branch of their profession, and created an *esprit de corps*; already they had a history and an influence.

Mr. C. Jones, the secretary, then delivered an address on "Sanitary Legislation and its Practical Exponents." In the course of it he referred to the employment of officers under the title of "Inspectors of Nuisances" to carry out the provisions of the Sanitary Acts.

Mr. E. B. Ellice Clarke, of Ramsgate, then read a paper on "Sewage Ventilation," in which he stated that the evidence he had obtained from nearly 100 towns showed a deplorably backward state of things as regarded the actual ventilation of the sewers. The conclusion he came to was that by far the most effective system yet adopted was the simple one of open gratings in the centre of the street. Crude it might be yet it had well answered its purpose, and it possessed many advantages over any system that had been attempted to deodorize the gases. It was not liable to get out of repair, and from its entire simplicity, was unquestionably superior to any other mode in diluting and dispersing the gas. With modification, he believed it to be the only way of ventilating our sewers

Mr. E. Monson followed with a paper on "The Sewage Difficulty; including the value and purification of sewage, farmyard, and artificial manures," which went to prove that as there was no demand for sewage, there was much difficulty in disposing of it, and as the result claimed for it might also be claimed for irrigation, sewage could not be utilized at a profit if it had to be pumped, but it might pay its expenses if utilized by gravitation, and that the attention of town authorities should be directed to its purification by filtration, and by utilization to a limited extent, as these required less land, and did not entail so much expense.

The President read a paper on the general subject. Mr. Prange described Whitthread's process, which consists "in adding dicalcic phosphate, dissolved in an aqueous solution of monocalcic phosphate, to the sewage as it flows from the sewers, and when the whole was well mixed, in adding milk of lime in sufficient quantities to precipitate all the phosphates, avoiding an excess of lime."

Dr. Anderson gave a sketch of the Sulphate of Alumina process which he is carrying out at Coventry, and which he expects will pay expenses and yield a profit.

Colonel Jones, V. C, read a paper on his mode of treating the sewage of the small town of Wrexham. Descriptions were afterwards read of the Phosphate process by Mr Tanner, of the Cement process by Major-General Scott, C. B., and of Milburn's process. Dr. Wilson, the Medical Officer of Health, said that many of the processes had been made Stock Exchange speculations, and had not therefore been put before the public so honestly as they might have been. Looking at the question from a purely medical point of view, he believed the water carriage system was the best system, and he had no hesitation in recommending the adoption of water-closets in all towns where there was a good water supply.

Subsequently Mr. T. A. Skelton read a paper upon "Gas Street Lighting," which described his Catropric lamp.

On Saturday the proceedings of the meeting were brought to a close by an inspection of the sewage works at Saltley, belonging to the Birmingham Corporation.—*Architect.*

IRON AND STEEL NOTES.

SLAG AS A BUILDING MATERIAL.—Mr. W. F. Hooper, Professor of Architecture and Building Science, Royal Polytechnic College, London, has published a letter on this subject. He says:—

"It is a matter of astonishment to me that colliery owners and others, who have such enormous quantities of this waste material at their command, have not utilized it to a much greater extent. In

it they have the most valuable material that it is possible to obtain for erecting the class of buildings they require; and yet they not only treat it as a waste, but they cover acres of valuable land as a shoot in order to get rid of it.

"As I have planned and superintended the erection of hundreds of buildings in concrete in different parts of the country during the last ten or twelve years, and have constantly used slag as an aggregate wherever I could procure it, perhaps a few facts from me respecting my experience of its use might be not uninteresting.

"It is now a well-known and established fact that where good aggregates, such as slag, gravel, broken sandstone, furnace ashes, or other hard material free from loam or clay, can be procured to combine with cement, concrete buildings are not only the cheapest but the most durable that can be erected. They are the cheapest because no skilled labor is required in their erection, so that the annoyance arising from the strikes of masons is avoided, and their durability has been fully proved, many having stood from time immemorial. But these are by no means the only advantages of concrete. Stone and brick, the ordinary building materials of this country, are more or less porous, and absorb not only a vast amount of moisture during wet weather, which requires weeks of fine weather or tons of fuel to evaporate, but they also absorb the animal gases, and in cases of epidemic are a main cause in the spread of disease. Now, with concrete this absorbent property is reduced to a minimum, as has been fully proved by erecting cisterns made of the material and although placed over the ceilings of rooms where the slightest leakage would be discernible, no damp has appeared. Thus for flat roofs it is invaluable, and its strength and tenacity are such that it can be used to cover large surfaces with but slight support.

"As I said before, slag is the very best material to use with cement for these buildings. Having been subjected to intense heat, all particles of loam, or clay, etc., that would tend to kill the cement and render the work rotten, have been removed, and its rough, honeycombed character forms a perfect key in the work. About two-thirds the quantity required should be broken either by machine or hand to the size of walnuts, with sufficient of smaller to fill up the cavities between; the remaining one-third should be used in lumps (but not larger than two-thirds the thickness of the wall), and packed in layers in the centre of the wall, the smaller, mixed with cement in the proportion of eight to one, being poured round."—*Architect.*

VALUE OF IRON WASTE.—A very important but, until quite recently, neglected constituent of the waste-heap are the old iron, battered saucepans, old pails, rusty hoops, horse shoes and nails from the road. All soldered articles have the solder extracted from them, as it is more valuable than the iron, and the cheaper metal is then melted. The horseshoe nails are not mixed with the common cast-iron, as they are much sought after by gun-makers for the purpose of making stub-twist barrels. Scraps of iron, it is found, may be made very useful in securing the copper in the streams washing veins of copper pyrites. Pieces of battered iron ore placed in tanks, into which these are collected: the copper, under these circumstances, incrusts the iron, and, in process of time, entirely dissolves it, so that a mass of copper takes the place of the iron, and the residuum, in the shape of a colored deposit, is at times taken out, dried and smelted. Thus, from the merest and apparently worthless waste, a large value is realized.—*Railway Register, St. Louis.*

THE total amount of pig iron made by the furnaces of Milwaukee in 1873, was 35,123 tons, about 500 tons less than the amount estimated at the beginning of the year. The total product of all the furnaces of Wisconsin was 73,983 tons

The contracts for the building and machinery of a new rolling mill at Milwaukee, Wis, for the Milwaukee Iron Company, are already let, and it is expected to have the new establishment in full operation by the 1st of September next. The main building will be of brick and iron, 80 by 216 feet and the capacity of the mill is estimated at 50 tons of bar iron per day. The company enters upon this new enterprise with every assurance of success, and it cannot be doubted that its advent marks a new era in the manufacturing industries of Milwaukee. It is the only link that has been wanting in the chain of facilities afforded by Milwaukee for the successful prosecution of iron manufactures of every description.

Ground has been broken for an iron furnace at Hacketts'own, N. J., between the railroad and canal, twenty acres having been set apart for it. The furnace is to be fifteen feet bosh, stack fifty-five feet, and will have a 400 horse power engine. It will be capable of turning out from 200 to 225 tons of iron per week.—*Engineering and Mining Journal.*

RAILWAY NOTES.

THE FASTEST TRAIN ON THE CONTINENT.—Probably the best specimen of an American highway to be found anywhere is the Pennsylvania Railroad, between Pittsburgh and New York. In solidity of construction, superiority of bridge architecture, and smoothness of track, it is unrivalled. Throughout its entire length it is laid with a double track of 60-lb. steel rails, fastened on oak ties, imbedded in broken stone ballast, with splice-joints between the ties, and so arranged that the connection on one side comes opposite to the centre of the rails on the other. The rolling stock is as near perfection as human ingenuity and skill has been able to make it. Locomotives and cars are alike built by the company at their own shops, and in the details of materials, design and finish, combine the highest excellence attainable. To all this is added a rigid policy of management, exacting the utmost care and courtesy from employees of every grade, and the application of those effective safeguards—the Westinghouse air-brake and the block-signal system—showing that whatever can be done for the safety of travelers has been done on this great line of railway. This high standard of excellence having been reached, the managers feel warranted in taking another advance step for the special benefit of through travel, and the 1st of June commenced running a fast daylight train from Pittsburgh to Philadelphia and New York,

with close connections at Harrisburg for Baltimore and Washington, on the following schedule:

Leave Pittsburgh	7:25 A.M.	Arrive Baltimore	6:55 P.M.
" Altoona	11:28 "	" Washington	9:02 "
" Harrisburg	3:25 P.M.	" Philadelphia	6:40 "
		" New York	9:30 "

The magnificent run of 444 miles is made with but three stoppages—the first, of only 5 minutes at Altoona, after a stretch of 117 miles; the second of 20 minutes for dinner, at Harrisburg, after an unbroken dash of 132 miles, and the third and last, of only 5 minutes at Philadelphia, after a run of 105 miles, leaving a single stretch of 90 miles across New Jersey to destination. No time being lost in stopping, the wonderful locomotive engines work away with the regularity of fixed machinery, taking their supply of water from the track tanks as they go, and carrying their fuel with them; and the time is made by uniformity of progress more than by an increased speed. The train is made up of Pullman parlor cars and the best of the Company's day coaches, all splendidly upholstered, mounted on combination springs, and furnished with plate-glass windows, through which the landscape can be distinctly seen. And here comes in the great charm of this daylight ride through Pennsylvania, for the train leaves Pittsburgh at 7:30 in the morning and reaches Philadelphia at 6:45 in the evening. On, on, on, goes the tireless train, over a clear track, carrying the traveller by a panorama, the like of which can be found nowhere else on this continent, and probably not in the world. After having breakfasted in Mississippi Valley and dined at the capital of Pennsylvania, the passenger finds himself at supper in the metropolis of New York. A few years ago a man who would have predicted such a ride would have been pronounced hopelessly insane. But it is a fact accomplished—a reality of the day, and all that is left for the people is to wonder and enjoy.—*Pittsburgh Commercial.*

SHALER'S COMBINATION SIGNAL AND FLASH-LIGHT.—This article is the very best of its kind in existence, and should be on board of every kind of vessel, steam or sail. It is the perfection of the lantern and flash signal. It is simple, safe, reliable and inexpensive, and its universal adoption and use would unquestionably be the means of saving many lives and much property. Its value consists in part: 1st. As an ordinary lamp or lantern. 2d. As a convenient danger or telegraphic signal, always ready and at hand in case of accidents, alarms, fogs, or threatened collissions. 3d. As a powerful illuminator in dark nights, rendering the smallest objects visible for many yards distant in all directions.

It has received the warmest commendations from all who have ever seen its operations. It is adopted by the Board of Supervising Inspectors of Steamboats, by the Navy Department, Life Saving Service, Coast Survey, &c. The Committee of the Board of Supervising Inspectors report upon it as follows: "It is a simple contrivance, and its effect as a Signal Flash Light is perfection itself." The invention is an improvement on Signal Lanterns for Railroads, and is equally useful wherever flash lights are required. It is an ordinary lantern, in which lard or sperm oil is used, with a separate reservoir containing naphtha or volatile oil held in suspension by cotton batting packed in a wire gauze sack, and by means of a cylinder or air-tube passing through said reservoir common air is injected and forms with the volatile oil hydro-carbon gas, that escapes through a tube adjoining the fixed light, creating thereby a brilliant flame a foot or more in length, and visible for a very long distance.

In connection with this invention, known as the Shaler Combination Signal and Flash Light, is a can, represented to be entirely safe, for the transportation of naphtha, it being provided with shields to its apertures of wire gauze, acting on the principle of the Davy lamp.

TRIAL OF A HYDRAULIC BRAKE.—A trial of the Henderson patent hydraulic brake was made on the West Chester and Philadelphia Railroad, July 21, and is thus reported by the Philadelphia *Ledger:*

"The train consisted of five passenger cars and one baggage car, attached to a large and powerful locomotive. It left the depot at 11 o'clock, and ran about ten miles up the road, during which several stops were made, and the workings of the brake thoroughly tested. The first stop was made on a grade with a descent of 15 feet to the mile, running at a speed of 35 miles per hour, when the train was stopped in a distance of 630 feet and in 20½ seconds time, with a boiler pressure of 105 pounds to the square inch. The second was made on a grade of about the same inclination, at a speed of 32 miles, and in a distance of 540 feet, at a boiler pressure of 115 pounds to the square inch. The third stop was on a level, at a speed of 35 miles an hour, and was made in 840 feet, in 28½ seconds time, with a boiler pressure of 105 pounds to the square inch. This stop was made by bell signal from the rear end of the train.

"The brake is under the control of and is worked by the engineer of the locomotive. The following description will give an idea of the manner of its operation. Between the wheels of each truck there is placed a cylindrical vessel of cast iron, whose ends are formed of two dish-shaped flexible diaphragms of India-rubber, secured to the drum, and making an air-tight joint at the periphery by flanges bolting thereto. Two rams working in opposite directions are fitted against and into the hollow part of the diaphragms, their outer ends are attached by rectangular flanges and bolts to the brake-beams carrying the brake-shoes. The several castings are simply bolted together, with the diaphragms, as they come from the foundry, without recourse to the usually expensive mechanical fittings.

"When pressure comes between the diaphragms, it simply forces them apart, projecting the rams, which act immediately on the brake-beams, applying the brakes; and when the pressure is relieved the atmosphere reacts on the area of the rams and forces them back, assisted by the tendency of the diaphragms themselves to recover their normal condition."

ENGINEERING STRUCTURES.

WORK ON THE GOSCHENEN SIDE OF THE ST. GOTHARD TUNNEL was advanced 82 metres during May, and on the Airolo side by about 45

metres; total 127 metres. By the end of May, 1823.40 metres altogether were accomplished, and on the 8th inst. 1840 metres. The progress at the Goschenen side was very satisfactory, considering the continuing hardness of the rock. In consequence of an accident by which several men were killed, the works were for a time almost interrupted, having a considerable influence on the advance of the work. An investigation has shown that the accident was due to a want of caution on the part of the unfortunate men. The three wounded are reported almost out of danger. On the Airolo side the works are very much hindered by the great influx of water. The low result of last month is, however, also attributable to sickness among the more skilled workmen and to the extraordinay tenacity of the rock, which resists sometimes even dynamite. The hornblende and gneiss formation encountered, though it was calculated that they would be met with, are not of great thickness, but they will be struck again. The results obtained during the last week of the month where somewhat better, and there is no reason for supposing that in Airólo also better progress will not soon be made. By the end of this month a sufficient number of the improved McKean boring machines, at present only partially employed, will be ready, and they will then be exclusively employed in the works of the tunnel.

ANOTHER DETROIT TUNNEL PROPOSITION.—The Detroit Board of Public Works have received a letter from Jerome Wenmacker, a French inventor, in New York, in which he makes a proposition to construct a tunnel under the Detroit River. His system is to pass under the stream with the crest of the tunnel nearly level with the bed, rendering the approaches shorter and less abrupt than they usually are; the depth of the water or the nature of the soil is of no consequence, and when the work is well organized it can be carried forward with greater rapidity than any work of similar magnitude on land can be. His plan embraces one coffer dam on each side, and two more at equal distances from the side dams further out. At each of these he would sink a shaft to the tunnel bed, and put on six gangs for the excavation. The earth, etc., could be taken out at the nearest shaft and the materials for construction passed through the same. The tunnel would have a flat bed, a semi-circular arch being constructed of masonry with buttress supports on each side. The cost for two tracks would, according to Mr. W., be about $600 per running yard, and for a 4-track tunnel about $1,000 per yard.

A NEW THAMES TUNNEL.—At a special meeting of the Greenwich District Board of Works, Mr. T. Norfolk presiding, Mr. Barlow, of Charlton, who was largely engaged in the engineering arrangements of the Midland lines of railway, attended to explain the details of a scheme to provide a road and railway communication from East Greenwich, across the marshes, to Blackwall Point, and thence straight across the river by a tunnel to Poplar, thus forming a direct communication from the East India Dock Road, on the north side of the river, to the Woolwich and Greenwich Road, on the south side. By means of a section he had prepared, it was shown that the relative level of the river and the land is peculiarly favorable for the construction of approaches to a tunnel passing under the Thames at the place proposed. The general gradient would be 1 in 40, and the length of the tunnel 600 yards. He called attention to the fact that east of Tower Hill there is no place where a crossing could be effected without involving the necessity of passing over or under existing docks or dock communications, except the point selected; and that eastward of this point the East India and Victoria Docks occupy the ground for such a further length of the river-side that a communication eastward of them would be of comparatively little value. Mr. Barlow stated, as his opinion, that a tunnel of substantial build, and of dimensions suited to the large and important traffic which would pass through it, might be constructed at a cost less than the average cost of the bridges in the metropolitan area above London Bridge. The cost of the work would necessarily be affected by the dimensions, a subject which would have to be determined by the Metropolitan Board of Works and their engineer. Mr. Barlow then said that the project, so far as he had described it, was a public road, but it happened that the same plan of crossing the river might also be used for railway purposes. On the north side there were five railway companies—the London and North-Western, the Midland, the Great Eastern, the Great Northern, and the North London—and there was a point on the railway near Canning Town, on the line owned by the Great Eastern, where all these companies had running powers; so that, by making a second tunnel for railway purposes, and uniting it to the Great Eastern system at this one point, the whole of the five railway companies could be brought across the river and obtain direct access to Greenwich, Woolwich, &c., and also unite with the South-Eastern system. Mr. Barlow stated that until the subject was fully reported upon he was not prepared to speak definitely as to cost, but his impression was that, if the Metropolitan Board of Works made the road by itself, the cost would be from £500,000 to £600,000, but that, if it was made jointly with a railway tunnel, its cost would be from £100,000 to £150,000. He believes it would be advantageous to the railway companies to take advantage of such an opportunity of obtaining a crossing of the river at this point. In requesting the earnest atention of the Board to this proposed communication, he did so in the full conviction that, if the Metropolitan Board of Works constructed it as a free highway, its cost would be amply repaid by the increased value given to a large area of property, by the saving of the expense of transport of a great amount of goods and merchandise now compelled to go round by London Bridge, by facilitating the intercourse between the northeast and southeastern districts of the metropolis, and by diminishing the delays and obstructions to the general traffic of London Bridge and several miles of streets.

ORDNANCE AND NAVAL.

THE POLYSPHERIC SHIP.—Mr. Charles Meade Barnes has produced a new kind of ship, which he calls the Polyspheric. The bottom is flat, and fitted with three inclined planes with square ends,

the effect being as though three tenths of a gigantic saw were moved through the water with the sloping portion of the teeth first. The intention is to lift the hull out of the water. Mr. Barnes thus describes the experiments he has made with his model:—"The first of the experiments was made with a 7 lb. model. This model was by the propelling power driven forward over the water 66 yards in 6 seconds, the rocket in that time having been completely discharged, and the model brought to a state of rest on the water. The average speed observed in this case was 33 ft. in a second, or about 20 knots an hour, but it may be assumed that at its greatest, the speed could not have been less than 25 knots an hour. The second experiment was made with a model of similar form, but of slightly different proportions, and weighing with the full rocket 3 lb. 3 oz. The distance run in this case was 105 yards, and this distance, the time being carefully noted by two independent observers, was performed in exactly three seconds, being at the rate of 63 knots an hour—a speed that will be allowed to far surpass any speed ever attained by any water-borne object before. The model, owing to the water space being limited, was driven into the bank before the rocket was fully discharged, otherwise more than double the distance of 105 yards might have been effected. Several months before I had made some very satisfactory experiments with this model, when it had attained in rough water a computed speed of 40 knots with 3 oz. of powder, so that the result now recorded was not greater than I had anticipated. The motion of both models was from the beginning to the end of their course completely steady, so as to give them more the appearance of sliding over smooth ice than of passing over the surface of water. There was scarcely any water disturbance, though each model had a fixed rudder of thin metal by which they were directed in an absolutely straight line. There was no splash at starting, and at the end of their course the decks were found unwetted, and so evenly was the motion maintained under the propelling force of the rocket that, had it not been for the draught of air, I feel sure that a set of ordinary chessmen set up on their decks might have remained without being displaced during their course.

"As I felt certain it would be asked what would be the effect of using a rocket to drive a model of the ordinary shape, it is as well to state that not long before I made the experiments now brought forward, I endeavored to propel a ship-shaped model weighing 6 lb. with a rocket of the same size and charge as those used for my inclined plane models. Immediately after the firing of the rocket the model was urged forward, and when the speed increased its fore part was lifted out of the water so as to cause the model to fall over, and thus the experiment ended amid smoke and total confusion.

"The first or larger model was 3 ft. 9 in. long and 5⅝in. broad, and floated when at rest in 1¼in. of water. The slope of the three parallel inclines was 1 in 18. The second model was likewise of solid fir, was 29½in. long and 4⅜in. broad, and floated when at rest in ⅞in. of water. Its three inclines were sloped to 1 in 17. When drawn slowly over the water these models are found to offer a larger resistance than models of the ordinary shape. This is evidently owing to the fact that at low rates of speed they carry a considerable quantity of water before each of the inclines. This they continue until the equilibrium between the horizontal pressure of the inclines forward and the pressure of the water in the contrary direction is destroyed. This action seems to take place suddenly, when the model at once rises in the water and passes over the mass of the hitherto obstructing fluid. No true lifting action of the water seems to take effect on the inclined planes until the water is relatively in full motion against them. Up to this period the water merely exercises a dead pressure against the inclines. When the vessel is fairly lifted and the water passes freely beneath its bottom, it will continue to override the water, which can no longer be removed in the brief time given for the vessel's passage, and to use this irremovable water as a support or fulcrum of infinite lubricity over which it glides with comparatively small and scarcely increasing resistance.

"On one occasion I used the 7 lb. model with a rocket of the same power as those employed in the experiments detailed, and found that over waves which might have had their intervals equal to one-half the length of the model there was no retardation whatever. The speed recorded and distance run was precisely the same as in a perfectly smooth pond. With other experiments for the same purpose I have always found that waves have not caused any increased obstruction to a model's course."

The facts are summed up by the author as follows:—"I now submit the question to an unprejudiced public, among whom no doubt will be found many who will repeat my experiments with the same results, and by their verification aid me in overcoming those countless difficulties which every inventor has to encounter, when the invention he offers is one that tends to change the foundations of wealth and runs counter to the prejudice and self-interest of large and important bodies of men."—*Engineer.*

BOOK NOTICES.

MILK ANALYSIS.—A Practical Treatise on the Examination of Milk and its Derivatives, Cream, Butter and Cheese. By J. ALFRED WANKLYN, M. R. C. S. 12mo, $1. New York: D. Van Nostrand. 1874.

We, in New York, have not yet adopted the elaborate means for preventing the adulteration of food which had for a long time been in operation when this book was originally published. When we have, the value of works of the kind may be better appreciated. Meanwhile, however, they are of use, not only on account of the practical information they contain, but also as directing public attention to a question of much importance, especially in the towns. The necessity of a supply of good milk is often regarded as merely a matter of convenience, justice or luxury. But it has been amply proved that the health and proper nourishment of children are very seriously affected by any deviation from the standard of purity in the milk supplied to them. Mr. Wanklyn, the author of the little work before us, has for some years devoted special attention to the

subject of milk analysis, both as a scientific investigation and for the information of local bodies as well as of the Government of Great Britain, and he has given us in a condensed form, the teaching of his experiences. Not the least important chapter in his book is that wherein he exposes the failings of the lactometer, upon which it has too long been the custom to rely, for testing the quality of milk. It has long been affirmed that a more untrustworthy device than the lactometer has seldom emanated from science, but we do not remember to have seen its defects so prominently explained by any previous writer. "It confounds together milk which is exceptionally rich with milk which has been largely watered." And Mr. Wanklyn mentions the case of one of the London prisons where the authorities are especially particular about their supply of milk. They allow no milk to enter the prison unless it comes up to the M mark on a certain lactometer. The mark is pitched very high, and the milk purveyor reaches it by skimming the milk. This will be readily understood when the composition of milk is remembered. The density of the fluid depends on the presence of sugar, caseine, and mineral matters. It is lessened by the presence of fat globules. Thus, one trick of the milk trade is actually encouraged by the lactometer. The milk is partially deprived of its cream first. This increases its gravity. It is then dosed with water until it is brought to the nominal standard. This, it appears, cannot well be discovered by an estimation of the cream afterward, for if the process have been properly performed the watered milk, says Mr. Wanklyn, will throw up the fat that is left on it more perfectly than unwatered milk. He therefore is of opinion that one of the first steps necessary to be taken in milk analysis is to abandon the use of the lactometer. Nor does he think that the creamometer is very much more to be trusted. "The only really safe and satisfactory means of examining milk is by means of an analysis of it." This consists in first determining the solids and the water. The fatty matters have next to be ascertained, which, being subtracted from the total amount of milk solids, gives the amount of "solids not fat," a knowledge of which is sufficient to enable a judgment to be come to as to whether or not the sample of milk has been watered.

In the principle of his analysis, Mr. Wanklyn does not pretend to offer anything new, but in the course of his explanation of the whole detail of the proceeding it will be seen that he has reduced it to an exceedingly simple form; and he has put the matter so plainly and explicitly that no one with any experience in laboratory work can fail to follow him successfully. We shall not attempt to outline the nature of that part of his book, which must be read; but it may be well to note a few of the results of his investigations. Samples of good country milk were found to contain an average of 12.45 per cent, of solid matters. But many of the dairies that supply London are within the metropolis; and it was found, from a similar number of samples of rich town-fed milk, the solids rose to 14.07 per cent. Out of fifty-six samples of milk examined in London only fifteen were unwatered or nearly unwatered. It appears, in fact, as the result of about 1,000 analyses that only about ten per cent. of the milk supplied to the British metropolis is genuine. As a fact, however, of more general importance in increasing the value of the analysis, it must be noted that the composition of milk is found to be very constant. Thus, variations in the diet of the cow show themselves rather in the quantity than the quality of the milk, always assuming that the animal is in good health. A comparison of the milk yielded by the poor and ill-fed Bengali cow in India with that from the highly-fed animals in England, showed very little difference between the two. But the amount given by the former was only a small fraction of that yielded by the latter. Mr. Wanklyn does not appear to have much faith in the theories of milk-poisoning, and the production of typhoid fever by the use of so-called infected milk. But his notice of this subject is very brief. It is in the other part of its contents that the chief merits of his book will be found, and as a concise practical contribution upon a subject of much hygienic importance we fully recognize its value.—*N. Y. Times.*

MANUEL D'ANALYSE QUALITATIVE ET QUANTITATIVE AU CHALUMEAU. Par H. CORNWALL. 8vo cloth, $10. Paris: Dunod. For sale by D. Van Nostrand.

This fine octavo of nearly 700 pages, is a translation into French of the excellent American edition of Plattner's Blowpipe Analysis. It will prove serviceable to those students who either from requirement or choice, pursue a technical study by aid of a text-book in a foreign language.

MINERALOGY. By F. RUTLEY, F. G. S. (Murby's Text-books.)

Mr. Rutley's little treatise on mineralogy has the merit of expressing in a clear and simple form the facts that are most wanted to be known by the general student of a science for which a small elementary English book is needed. The descriptions are concise, and the selection of the matter under each mineral generally good. Mr. Rutley, furthermore, gives some fifty pages of preliminary matter, which, though not always put in the most intelligible form, yet embodies a considerable amount of useful technical teaching in regard to the physical properties of minerals. Mr. Rutley even enters, and very rightly does so, on the subject of optical characters. But in these pages, as in the page on thermo-electricity, the author does not seem to have carefully revised what he wrote, or he would not have followed other authors in speaking of boracite as a uniaxal crystal, and would hardly have classed the dispersion of light by a diamond with the play of color exhibited by an opal. Nor is an optic axis correctly described as the only direction by looking along which the doubly-refracted images of a spot can be got to coincide, as Mr. Rutley will see if he looks at the spot through two opposite faces of the hexagonal prism of a calcite crystal. He ingeniously endeavors to indicate the nature of the faces of his crytals by a sort of heraldic hatching and marking The use of small letters always indicating the character of the faces, as in Des Cloizeaux and other French treatises, might have done this usefully; Mr. Rutley's puzzling figures will probably only serve to scare away the English student, who needs every allurement to the study of the neglected science of crystallography—a science neglected merely because the rudiments of

geometry and trigonometry are not made a necessary part of every scientific student's education. And it is a significant circumstance in connection with this neglect of scientific crystallography, that the geometrical methods and simple notation introduced forty years ago by our distinguished fellow-countryman, the first living crystallographer, Prof. Miller, are, we believe, untaught in any single lecture room in London.

THE MARTYRS OF SCIENCE. By SIR DAVID BREWSTER. New Edition, with portraits. London: Chatto & Windus. 1874.

This is a re-issue of an old and excellent book, consisting of the biographies of Galileo, Tycho Brahe and Kepler, three of the great lights of astronomical science. The tale of their lives is well and impartially told. They were troubled beyond what one would naturally expect to find in the case of men devoted to what apparently ought to be the quietest and most contemplative of pursuits; but after a careful perusal of their stories, one cannot help thinking that, not even excepting Galileo, they brought a great deal of their life-sorrows upon their own heads. A little bending to the inevitable, a better command of temper, and more attention to time and circumstance, would have enabled all of them to turn the flank of their perplexities without detriment to the truths which had been given them to proclaim.—*Iron.*

TREATISE ON PRACTICAL SOLID OR DESCRIPTIVE GEOMETRY; EMBRACING ORTHOGRAPHIC PROJECTION AND PERSPECTIVE OR RADIAL PROJECTION. By W. TIMBRELL PIERCE, architect, late Lecturer on Geometrical Drawing at King's College and Harrow School. With eighty-eight Plates of Original Drawings. London: Longman, Green & Co.

Mr. Pierce informs us in his preface that he has been induced to write this work from the want felt of a good English text book on the subject, and we agree with him that in this respect our technical literature has been behind that of France and Germany. The want just referred to Mr. Pierce appears to have well filled, and his treatise contains an extensive series of problems clearly treated and illustrated by diagrams well drawn and engraved to a large scale. The letter-press descriptions, too, are sufficiently full to enable a student to follow the problems without further explanation from a teacher, a point of importance to many.

MANUAL FOR RAILROAD ENGINEERS AND ENGINEERING STUDENTS. By Prof. GEO. L. VOSE, C. E. Boston: Lee & Shepard. Price $12.50. For sale by D. Van Nostrand.

This is the second edition of this excellent work. The two former volumes now appear in one, and at a price considerably below that of the old edition.

The book is absolutely indispensable to the railway engineer, or to the engineering student who aspires to a knowledge of the practical in railway matters.

From the reconnoissances to the management of the running work, everything pertaining to this branch of Civil Engineering is fully and successfully treated.

The illustrations are abundant and well executed.

The advertisement to be found in another page specifies the topics in their order of treatment. At another time we will speak at greater length of the merits which fit this work for students.

MISCELLANEOUS.

TIN glaze, for pottery, originated in the East. Stanniferous glazes are found with Egyptian mummies, on the splendid productions of the Persian potter, whose date we can only guess at, and in tiles from the Moorish palaces of Southern Spain. It is, then, to be supposed that this secret lay long dormant among Oriental races, and was revived and communicated to European nations, with so many other half-lost arts by the Arabs, and Moors who conquered Spain. Tiles with tin glazes are found in the Alhambra, with a date corresponding to 1300 A. D., and there is no doubt that the Moorish potteries were established in this and the following centuries in Spain, in Portugal, and in Sicily, and wherever else the Moors had made their settlements. The Moorish potters made a very beautiful ware, known to collectors as Hispano-Moresque, and easily recognizable by the peculiar metallic lustre on its surface. This ware was largely exported from Spain to Italy, insomuch that the finest pieces are to this day found in that country, and not in Spain; and in time the Italians began to set up potteries of their own, and to imitate the Moorish ware. They called their imitations Majolica, or Maiolica—the ancient Italian name of Majorca—either because the Moorish pottery was made there or thence brought, or because the Italians fancied that it was. At first the Italian potters could not compass either the lustre of the Moorish ware or the rich, enamel like glaze of these foreign potters, and their first works were lead-glazed, and are known to collectors as half Majolica—"Mezza Majolica;" but towards the end of the fifteenth century they began to imitate the lustred wares. At last they got hold of the great tin secret, and their pottery soon surpassed the Hispano-Moresque wares in beauty. In the Moors' own specialty of lustred wares they were excelled by the Italians, and at the town of Gubbio a mode of imparting a lustre of a red color of surpassing beauty was invented—a secret that was never disseminated, and soon lost; and the rare ruby-lustred plates of Gubbio are now among the greatest treasures of the art collector.

A RELIC OF THE MOUND BUILDERS.—Dr. H. H. Hill, one of the most enthusiastic and successful collectors of American relics, on a late excursion to Ironton, discovered the great sandstone anvil of these wonderful people. It was found about two miles above Ironton, on the farm of Mr. Luke Lelly. It is composed of very sharp grit, contains over one hundred depressions, weighs about five hundred pounds, and measures eight feet eight inches at its greatest circumference. It will be placed in the rooms of the Cincinnati Society of Natural History, to which society the doctor proposes to present it.—*Iron Age.*

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A PRACTICAL THEORY OF VOUSSOIR ARCHES.

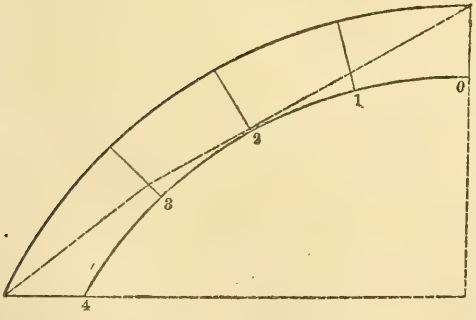
(Continued from October No., page 303.)

Eleventh Experiment.—Fig. 13. With this same Gothic arch a segmental circular arch was now made of 24.24in. span, and 7in. rise; the voussoir being as before 2. deep and 3.65 thick.

With 7.6 vs. on the summit, this arch *balanced;* the weight being placed on a small stick resting on the summit. With a greater weight rotation occurred on joints 0, 2 and 4, the crown falling.

	s.	m.	S.	M.	C.
	3.8	0.00	3.8	0 00	.00
1	1.	2.03	4.8	2.03	.42
2	1.	5.90	5.8	7.93	1.37
3	1.	9.38	6.8	17.31	2.55
4	1.	12.11	7.8	29.42	3.77
	7.8	29.42			

Fig. 13.



On trial it was found that the true line of pressures passes .15 from the edges at joints 0, 4 and 2; giving the characteristics of both a maximum and a minimum thrust. We find

$$Q = \frac{7.8 \times 10\ 45}{8.85} = 9.21\ vs.$$

This horizontal thrust is greater than we have hitherto had, and probably accounts for the line of pressures retreating .05 further, in the arch ring, than we found for the Gothic arch. The construction is precisely similar to previous ones; the dotted line in Fig. 13 representing the line of pressures.

The ends of this arch required fastening tacks thrust into the board and pressing against voussoirs 4, .03 above the springing as in the first exp., with the Gothic, to prevent sliding. The thrust on joint 4 made an angle of 50° with the normal to that joint.

12*th Exp.*—With this arch resting on piers 3.63 wide, 5.8 high and 2. thick, each weighing 1.5 vs. the inner edge of pier being on a line with the springing, the arch balanced with .5 vs. on the summit.

We find, by constructing a line of pressures passing .15 from summit and the intrados at the third joint, that it cuts the base of pier .24 from its outer edge. Real arches have no mathematically plane joints, and therefore bear on the most elevated points.

This of itself may account for any *slight* discrepancies that we may meet with.

Some of Mr. Bland's experiments may now be tried, and they will be found to agree with the theory above ennunciated.

Thus in his first experiment, with a semi-circular arch of 24 in. span, the voussoirs being of wood, 2.5 deep and 4 thick, the arch being composed of 20 voussoirs; it stood with a weight equivalent to 2 vs. on the summit; falling with 2.5 vs.

The line of pressures passes very near the extrados at the crown and springing joints, and very near the intrados, half way between the crown and springing.

As in this experiment the weight probably bore on some extent of surface at the crown, and as the details of the method used to keep the bottom voussoirs from sliding are not given, and as besides the arch could not have been an exact semi-circular, if the voussoirs were 2 in. in *length* (along their centre line from middle to middle of joint) the construction evidently shows only an approximation to the truth. The same remark applies to some other of the experiments.

The second exp. with a segmental arch is equally illustrative of the theory advanced, as also Exp. 5. In Figs. 51, 52 and 53 of arches on low piers, we likewise have a proof of the theory in question.

Fig. 51 of Mr. Bland's treatise represents the semi-circular arch just mentioned, *balancing* on piers 7 in. high, the base measuring 4x4. The line of pressure passes near the summit, near the intrados at about 30° above the springing and near the outer edge of pier.

The lines of pressure in the arches, Figs. 52 and 53, pass through, or very near the summit and springing, and the outer edge of the piers.

Figs. 55 and 57, of Mr. Bland's treatise, represent Roman arches on piers, which, together with Figs. 54 and 56 of Gothic arches on piers, and Figs. 45 and 46 of Roman arches with weights on them (exps. with low piers), may be used to further illustrate Dr. Scheffler's theory.

In Chapter III of Mr. Bland's book are given numerous experiments of the effects of a horizontal force applied to the top of vertical piers built up of bricks of various heights and areas of base.

The reader will probably be surprised to find that, in the first 32 experiments given, if we regard the piers as *solid*, the actual horizontal forces exerted, to cause tumbling or rupture of some kind, was only three fourths, on an average, of the theoretical force required to cause *overturning* about an edge. The manner of rupture is not given by Mr. Bland, but it is evident especially from a consideration of his Fig. 26, that rupture was caused by *sliding* or sliding first and overturning afterwards.

In the few experiments of this kind by the writer, sliding usually occurred, even with brick piers; though overturning followed the sliding. Each brick seemed to have a different coefficient of friction, so that for these light piers, sliding often occurred some distance down from the top; though for blocks with the same angle of friction, the sliding ought to have occurred at the top.

It is true that in any case of overturning, the pier breaks along a diagonal and compresses at the edges, so as to cause leaning before overturning; but this cannot alone account for the discrepancy mentioned above, perhaps.

13*th Exp.* To form some idea of the action of mortar of different degrees of hardness, pieces of cloth .07 thick when not pressed, and .04 thick when pressed between two flat surfaces by the hands were put between the joints of the Gothic arch, (Fig. 11), each piece weighing .015 voussoir.

The span was then altered until the joints were all close, when it was found to be 14.57, the rise to the apex being 14.55. On placing a drawing-board by the side of this arch and tracing its contour curves, they were found to be very nearly arcs of circles, though not with their centres at the springing points. To locate them; measure horizontally from the springing points .32 towards the middle of the span, and then vertically downwards 0.1 to the centres, from which the arch may be drawn.

This arch balanced with 4.6 vs. at apex.; fell with 4.65 vs. The limiting lines to the curve of pressures, was found to be distant .3 $= \frac{1}{7}$ depth of joint from the contour curves, at its nearest approach to them.

This arch spread outwards upon the application of the weights, joint 2 being the point of rupture at the haunches; hence it is evident that if there had been a solid spandrel, or in this case, simply the pressure of the hands, to resist this

spreading, that the arch would not have fallen. The spandrel would have supplied horizontal forces in addition to the vertical ones due to its weight.

If the spandrel were not solidly built, at least up to joint 2, there would necessarily be derangement of the arch.

The curves of pressure were drawn in all the foregoing experiments, not taking into consideration the last mentioned derangement of the arch; which, in the last case especially, would have caused this curve to pass nearer the edges.

In fact, in most of the experiments, just before rotating, the edges alone seemed to be bearing. In the case of the simple Gothic, without cloth joints, when a sufficient weight was applied at the summit, the joint there, and joint 2, opened sensibly before the balancing weight was put on. The segmental arch flew out at the second joints, falling at the crown, only opening when near the balancing point.

Isolated weights applied at the summit, do not occur in practice, and it is hardly probable that a well-built viaduct, whose intrados is a segment of a circle, and of the proportions given in Fig. 9, with their joints only $\frac{1}{4}$ in. say, will spread appreciably after the mortar has well set; and this is necessarily a stronger form of arch than the semi-circular, elliptical, or hydrostatic, where the spandrel thrust is generally required to cause stability.

If the latter profiles are desired, let the depth of the voussoirs be increased towards the abutment, so as to keep the line of pressures within the proper limits of the arch ring, when the constructor will be assured of stability.

It certainly seems singular, that engineers should ever *recommend* an arch like the hydrostatic, which necessarily requires a very effective spandrel thrust to keep the arch from tumbling down.

The spandrels must in such cases be built with the same care used with the arch stones; thus increasing the *expense*, while really losing in *strength*.

14*th Exp.* In the joints of the same Gothic arch, pieces of soft woolen cloth .15 thick when not pressed, and .1 when pressed hard between two bricks by the hands, were next inserted, each piece of cloth weighing .027 voussoir. The span, when the joints were close, was found to be 15 in.; rise to apex, 14.63. The centres for describing the contour curves were 1.07 in. from the springing points measured horizontally towards the middle of span.

This arch balanced with 2.3 vs. on the apex.

Assuming this arch to preserve its figure, the curve of pressures passes about one fourth the depth of joint from the edges at its nearest approach to them.

This experiment gives us some idea of the effect of thick plastic mortar joints or of uncentreing an arch with fresh mortar joints.

15*th Exp.* A Gothic arch of about half the dimensions of the first given in *Exp.* 1 was cut out; really, before the arch we have just been considering.

It was not found to be symmetrical as to weight, one half weighing $\frac{1}{32}$ of the whole arch more then the other half. Still as arches in practice are unsymmetrical as to weight at least; it will be interesting to know, that assuming this arch to be symmetrical the curve of pressures passes .075 from the edges at the joints of rupture, more especially with weights at the apex.

All the preceding experiments were repeated with this arch and the same laws approximately established.

In the experiment with the cloth joints, the cloth was .05 thick not pressed; .04 when pressed hard by the hand. The curve of pressures was found to pass .1 from the edges at the joints of rupture, with a weight on the apex, and nearly so in the pier experiment with no weight on the apex.

16*th Exp.* Mr. Bland gives, (p 21,) an example of a Gothic arch of 24 in. span, voussoirs 2.5 deep, which fell of its own weight; though it was partly built of flat bricks, which accounts for its falling, for on making an arch of the above proportions it not only stood easily, but all the above principles were approximately established by it. The arch was not perfectly symmetrical as to weight, and was composed of 16 voussoirs; span 10.7 in.

The line of pressures passed within .075 of the edges at the joints of rupture.

The arch given by Mr. Bland, was probably not a true Gothic, or the joints did not fit along their whole extent; a sufficient hint to the constructor to exercise every care in these particulars in building.

It is to be regretted that in the experiments given by Mr. Bland, where backing was used, that he does not state its thick-

ness, except in the case of some experiments with models of bridges.

In the model of the Rochester bridge, Fig. 81, where the backing was carried up on a level with the summit of the arch ring, the line of pressures will be found by the method of Art. 8 to pass very near the edges at the summit, the springing and the outer edge of pier.

This experiment especially shows the error of passing a curve of pressures through the middle of the joints at the crown and springing, or within the middle third of the arch.

The bridge would have tumbled on either supposition. This bridge was 100 ft. span, and 15 ft. rise; the model having a span of 15 in. and a rise of 3.75 inches.

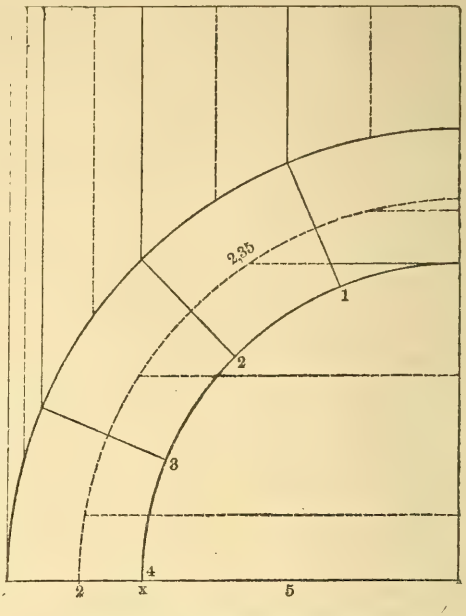
A series of extensive experiments on large arches, of stone or even wood, somewhat after the manner of these, is much to be desired as they would show us practically the effect of the compressibility of the materials upon the line of pressures.

Thus suppose stone or even wood arches of 10, 20, 30, 40, 50 and 100 feet spans to be cut out, and the balancing weights, at the crown, found. The distance that the line of pressures retreats from the edges follows, and we thus have practical data to work from, in designing similar arches; besides the law of that compressibility may be approximately found.

An example will now be given of a combination of the method used by Dr. Scheffler and that by the writer. Calling r, in Fig. 14, the radius of the extrados, r_1, that of the intrados and n the proportion of the circumference included by the voussoir, we have its content $= \frac{\pi(r^2 - r_1^2)}{n}$ for a thickness of 1. Now this is equal to $\left[\text{the depth}, (r - r_1) \times \text{the } \textit{middle length } \left(\frac{2\pi(r + r_1)}{n \times 2}\right)\right]$ $= \frac{\pi(r^2 - r_1^2)}{n}$; hence measure the middle length and depth on a drawing, their product will give the required volume.

We now form the following table for Fig. 14, where the dimensions of the voussoir are given just below the dimensions of the corresponding surcharge. This manner of considering the voussoirs and surcharge separately is continued until in columns S and M, the quantities referring to the same joint are combined by the continued addition of the quantities in columns S and M separately.

FIG. 14.



	w	v	s	c	m	S	M	C
	2.7	2 13	5 79	1 38	7.99			
1	2.35	2.	4.7	1.18	5.55	10.49	13.54	1.29
	2 2	3 16	7.17	3.88	27 82			
2	2 35	2.	4.7	3.36	15.79	22.36	57.15	2.55
	1 7	5.	7.55	5 77	43 56			
3	2.35	2.	4.7	5.03	23.64	34.61	124.35	3.59
	0 7	7.2	3.6	6.77	24.37			
4	2.35	3.	4 7	5.92	27 82	42.91	176.54	4.11
			42 91		176.54			

If the voussoirs are taken the same size, there is really no necessity of entering their dimensions; simply giving their common area in columns.

This manner of computing the surfaces (S) and their lever arms (C) is particularly applicable in the case of tunnel arches, which often have quite a depth of voussoir; as for example the Thames Tunnel, whose span is 14 feet, the depth of the arch ring being 3 feet.

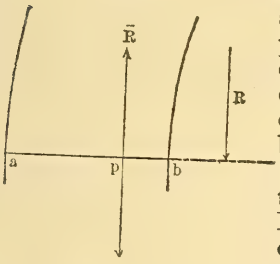
This method gives all the accuracy that is necessary in practice; expecially as arches are never symmetrical as to weight, and besides their spreading, if any, at the haunches requires an allowance to be made.

In experiments with arches with a backing, this method is especially applicable, particularly with full centre arches.

The decimals in the foregoing table are not carried out as far as they should be in practice.

10.—The manner in which rotation occurs in an arch will be made clear from a consideration of Figs. 6 and 15. Suppose the resultant R to pass outside the arch ring at any point, and that it is not opposed by any resistance there; next conceive two equal opposed forces, ‖ to R, to be applied at some point p (Fig. 15) of the joint. This evidently does not disturb the equilibrium.

Fig. 15.



We see, that there is a couple R R̄ formed together with a force equal and ‖ to R acting in the direction of R at p; which last is resisted by the compressive reaction at the joint. The couple R, R̄ can only be resisted by a couple; hence if there are tensile forces towards a, to be combined with the compressive reactions, a *resisting* couple may be formed of sufficient moment to maintain the equilibrium, and this is what usually happens in a solid arch of cast iron or concrete, etc.; but it is evident that if the joint can supply no tensile resistance, as in the case of a plane joint without mortar, or with mortar whose cohesive strength is null, then rotation must occur, as there is an unbalanced couple to produce it.

In fact (see Fig. 6) if the resultant R in any compressible arch, without tensile resistance at the joints, approaches nearer the edge than *its limiting* position, an unresisted couple is at once formed and overturns the arch.

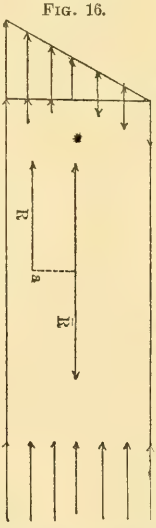
To consider the voussoir arch, whose joints can supply no tensile resistances, further, let us suppose first, the resultant R, (Fig. 6) to be in the centre of the joint; the forces f- - -, f'- - - may for a small joint be regarded as uniformly distributed. Suppose now the resultant R to move towards the edge b, slightly; there is still only *compression* on the joint, though its distribution is according to some unknown law. There is no couple formed until R has passed its limiting position, as is clearly shown by the preceding experiments; otherwise rotation would have occurred, which however did not happen.

In fact in moving the position of the resultant (Fig. 6) from the centre of the joint towards b, the stress becomes greater at b than at a; and some line $s\,s'$ will limit the values of the elementary forces f- - - - f'- - - -, representing them by arrows as in the figure.

We cannot, however, locate the line $s\,s'$ with our present knowledge, except in certain positions of R for solid arches, where actual tensile forces are brought into play; the usual theory for that case being as follows: Suppose the resultant R to be treated as in Fig. 15, the two equal opposed forces being supposed applied at the neutral axis or centre of gravity of the cross section of the beam.

The couple R R̄ is resisted by the tensile and compressive resistances, acting respectively on either side of the neutral axis, as in the case of ordinary flexure of a beam. The remaining force, acting ‖ and in the direction of R, at the neutral axis, being decomposed into its elements, adds to some of the forces brought into play by the couple R R̄ and subtracts from others.

Fig. 16.



Let us suppose the resultant R to approach the centre of gravity of the cross section; when it reaches a point a, which is $\frac{1}{6}$ the depth of beam from the centre of gravity, for a rectangular cross section, varying for other forms, there are no real tensile forces exerted at the joint (Fig. 16); and as a approaches nearer the centre of gravity the determination of the elementary forces at any point becomes uncertain.

In the solid arch, when R is farther from the centre of gravity than the point a, tensile forces are exerted about the farther edge, which, together with the compressive forces, form a couple, which transports the resultant R nearer the centre of gravity of the cross section.

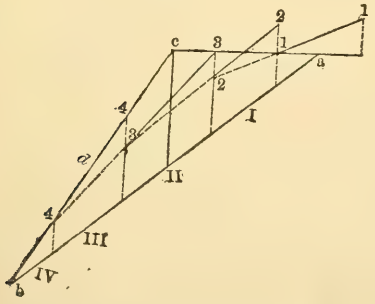
In the voussoir arch, whose joints oppose no tensile resistance, however, there is no resisting couple to effect this transfer of the resultant, and it is absurd to suppose the two equal opposed forces at the neutral axis, in which case the arch cannot be supposed to resist the couple

inevitably formed; with the same propriety might the two opposed forces be supposed, in the first instance, on the farther side of the arch ring; and yet certain authors seem to think that the line of pressures cannot pass outside the middle third of the arch ring without a couple being formed, and rupture ensuing, whereas our experiments have clearly proved that for the arches used this line of pressures passed on an average only $\frac{1}{8}$ the depth of joint from the edge at the joints of rupture, without rupture ensuing.

As the joints opened in many of the exps. before rotation occurred, it is evident that if the joint had been capable of offering tensile resistance, that it would have come into play, and prevented the opening; thus carrying the resultant nearer the centre and causing a more equal distribution of the resistance on the joint, than where the arch opposed no tensile resistance. Hence the utility of concrete arches, which can oppose such resistances, as also of solid metal and timber arches.

A good illustration of the agreement between algebraical formulæ and graphic construction, may be had from a consideration of two inclined rafters leaning against each other, one of which (supposed of very small cross-section) is represented by *ab* in Fig. 17.

Fig. 17



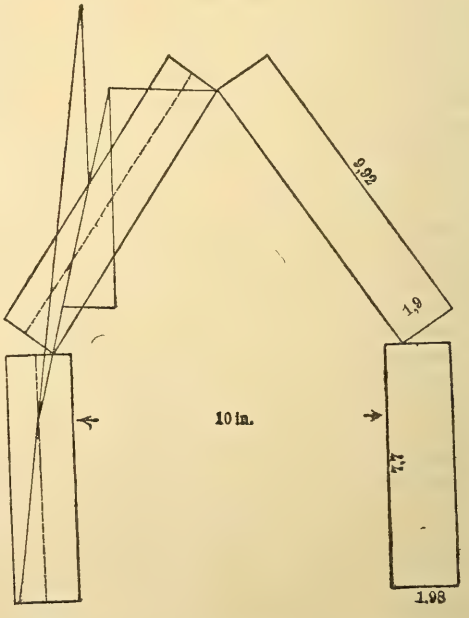
Reasoning as in Art. 2, we see that the thrust at the crown is horizontal; and if $\overline{c\,\mathrm{II}}$ = weight of beam drawn through its centre of gravity, $\frac{1}{2}\,c\,a$ is the horizontal thrust.

Divide the length of the beam into any number of equal parts, four in the figure; combine as by the ordinary method, the horizontal thrust, at *a*, with the weight of the first division of the rafter, acting through its centre of gravity. Combine this resultant with the weight of the next division and so on. The last resultant $\overline{44}$ should pass through *b* and equal the thrust there, $\overline{cd}$ and act in the same direction. The other method of construction abopted in this article may likewise be used, particularly for many divisions of the rafter. The bending moment on joint I is the length $\overline{\mathrm{II}}$, multiplied by a perpendicular, from the neutral axis at joint I, to its direction; that on joint II is $\overline{22} \times$ perpendicular from II, to its direction and so on for the others.

Now if by the usual formulæ for an inclined beam, we calculate these moments, they will be found to exactly correspond to those found above, mostly by graphic construction. The *curve of equilibrium* $\overline{a\,1\,2\,3\,4\,b}$, as the curve of pressures is sometimes called, is, for a beam of uniform weight per unit of length, a parabola, whose vertex is at *a*, as is well known.

The component of any resultant, perpendicular to the beam, is the shearing force on the joint to which the resultant corresponds; the parallel components give the direct compressive force on the beam.

Fig. 18.



By algebraical formulæ, we know that the bending moment at I is equal to that

at III, that at a and b, being zero; also the shearing force at a equals that at b, at I, that at III; all of which we find by this partly graphic method.

Figure 18 represents two rafters 9.92 in length, 1.9 width (dimension in plane of paper) and 3.60 thick, leaning against each other at the top and against piers 7.7 high, 1.98 wide and 3.6 thick at their bottom edge, which is moved back 0.6 from the edge of the pier. The horizontal distance between the vertical piers is 10 in.; so that the feet of the rafters are 11.2 apart. Each rafter weighed 2.3 vs.; each pier 2. vs. The rafters and piers just balanced in this position.

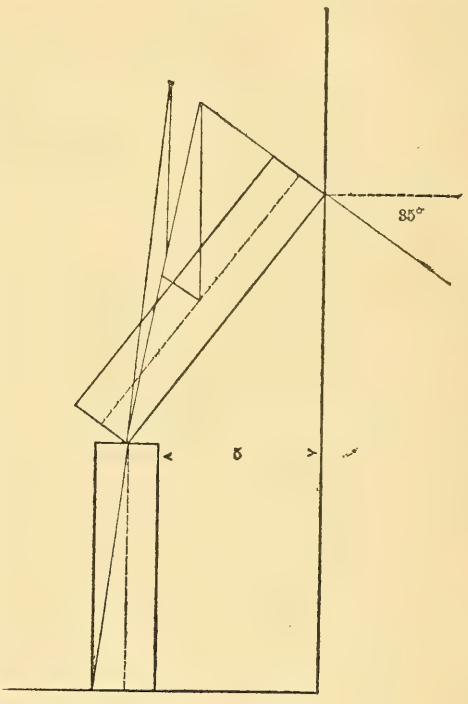
Reasoning as in Art. 2, we see that the thrust at the upper edges of contact of the rafters is horizontal; hence draw a vertical line through the centre of gravity of the rafter equal to its weight; the resultant on the lower edge of the rafter passes through this edge, which combined with the weight of the pier acting through its centre of gravity, gives the resultant thrust on the base of the pier. In this case it strikes twenty-two hundredths(.22) from its outer edge.

There is to be found in many standard works an erroneous theory of this case, which supposes half the weight of the two rafters to be suspended at the upper points of contact. If the reader will decompose this weight into its two components acting along the rafters, and then combine a component with the weight of the pier, he will find that the final resultant will pass .83 outside the base of the pier, and yet it stood well. The same thing may be seen on investigating Mr. Bland's exps. on rafters, p. 70. Until such palpable errors as we have noted along, are expunged from text books, the young engineer cannot be said to have a safe guide in the theory of his profession; and y^e old practical man will ever smile at the attempts to reconcile theory with practice.

The next Fig. (19.), represents a rafter and pier of the preceding experiment; the rafter leaning against a vertical rough plastered wall by its edge, the lower edge resting on the pier 1.03 back from its inner edge. This was the balancing position. The construction is as before explained in Art. 1, for Fig. 1.

After several trials, assuming as we found in the preceding experiment that the resultant strikes .22 from the outer edge of the base of pier, it was found that the direction of the thrust against the wall was inclined about 35° to the horizontal, which is about what we should imagine the angle of friction of the edge on the wall was. This proves the first proposition in Art. 1. Even if the thrust at the upper edge be assumed horizontal, it will be found that the final resultant passes outside the base of pier; hence, such an assumption is false. The construction (Fig. 19.) by extension, will also show that .32 v. of the rafter is sustained by the wall, 1.98 v. being supported by the pier; *i. e.* about one seventh of the weight of the rafter is upheld by the friction of the plastered wall.

Fig. 19.



On leaning a half arch against a wall, it was found to balance on higher piers than when the other half was placed against it.

11. It would be beyond the scope of this article, to follow Dr. Scheffler in the discussion of horizontal, as well as vertical forces applied to the arch, which however presents no difficulty. As all inclined forces can be resolved into vertical and horizontal components, it follows

that his discussion applies to any form of arch, solicited by forces inclined in any direction. A profile may be designed, by simply assuming first some form of arch deemed the best; then drawing its curve of pressures for the load passing through the middle of the joints at the crown and springing, and taking this curve as the centre line of the desired arch ring, when it will generally be found that the curve of pressures for this last arch will remain everywhere within the proper limits; a second trial being rarely, if ever needed, in practice.

Thus we find that the strongest form of arch, with a very high surcharge of masonry is the parabola. Dr. Scheffler found by a construction of this kind that the ellipse was the best form for an underground tunnel.

The simplicity and accuracy of Dr. Scheffler's method must commend it to practical engineers.

UNSYMMETRICAL ARCHES.

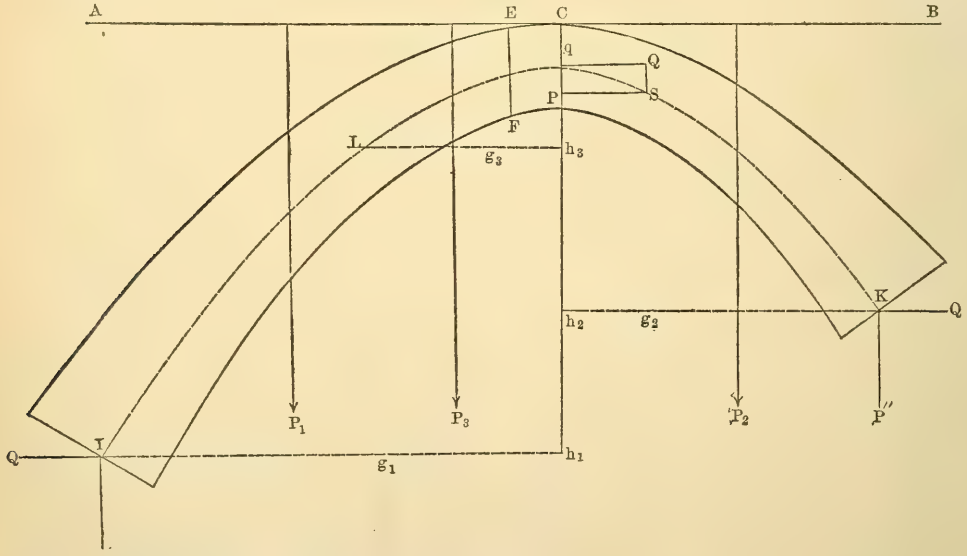
12. Dr. Scheffler demonstrates in this case, for incompressible voussoirs, what curve of pressures corresponds to the minimum of the thrust, and is therefore the true one. It would lead us too far here to enter into this discussion. The most usual case, being probably the only one met with in practice, furnishes this characteristic for the minimum thrust; *that it has two points of contact with the intrados and an intermediate point common with the extrados,* which is identical with what we have before found for symmetrical arches. This case includes that, where the points of meeting the intrados are at the springing.

There is a joint, EF (Fig. 20) generally near the crown at which the thrust is horizontal. Where the arch is only solicited by vertical forces, by compounding them with this thrust, as before, we find the resultants on every joint, and it is evident in this case that the horizontal thrust is the same all through the arch.

It is more convenient however, to find the inclined thrust at the crown and combine the partial weights with it, to find the resultant on each joint.

Problem: To find this inclined thrust and its point of application:

FIG. 20.



Let I, L, K be three points through which we wish to pass a curve of pressures (Fig. 20) $\overline{ACB}$ a horizontal line drawn through the highest point of the extrados, and let there be:

Q the horizontal thrust, *i. e.* the horizontal component of any one whatsoever of the pressures acting through I, L, K.;

P the vertical component of the pressure S at the crown joint, which will be considered positive, if it is directed upwards, as regards pressure from the right

part upon the left; in fact P may be regarded as a supporting force, when to the right of the joint E F, for if the arch only extended to C, P would be the weight that would be supported or resisted there; and so for any point of the arch to the right of E F.

Let q, be the vertical distance of the point of application of S below the horizontal $\overline{ACB}$; g_1, h_1; g_2, h_2; g_3, h_3, the horizontal and vertical co-ordinates of I, K and L as to the point C as the origin;

P^{I}, P^{II}, P^{III}, the vertical components of the pressures acting through I, K and L;

P_1, P_2, P_3, the weights of the segments C I, CK, CL, with their loads;

p_1, p_2, p_3, the horizontal distances of the centres of gravity of these segments from the point C.

To abbreviate, let us put:

$g_1 - p_1 = a_1$	$g_2 - p_2 = a_2$	$g_3 - p_3 = a_3$
$h_1 - q = b_1$	$h_2 - q = b_2$	$h_3 - q = b_3$
$g_2 \times g_3 = d_1$	$g_1 - g_3 = d_2$	$g_1 \times g_2 = d_3$
$h_1 - h_3 = e_1$	$h_1 - h_2 = e_2$	$h_1 - h_2 = e_3$

We have:

$$P^{I} + P = P_1 \quad \ldots\ldots (1)$$
$$P^{II} - P = P_2 \quad \ldots\ldots (2)$$
$$a_1 P_1 - g_1 P = b_1 Q \quad \ldots\ldots (3)$$
$$a_2 P_2 \times g_2 P = b_2 Q \quad \ldots\ldots (4)$$
$$a_3 P_3 - g_3 P = b_3 Q \quad \ldots\ldots (5)$$

If the third given point L of the curve of pressures is upon the joint at the crown C, the value of q is known, and we have: $g_3 = 0$, $h_3 = q$, $P_3 = 0$. From eqs. (3) and (4) we find

$$P = \frac{b_2 P_1 - a_2 b_1 P_2}{g_1 b_2 + b_1 g_2} = \frac{a_1 e_1 P_1 - a_2 e_2 P_2}{e_2 d_3 - e_3 d_2} \quad \ldots(6)$$

$$Q = \frac{a_1 P_1 - g_1 P}{b_1} = \frac{a_1 d_1 P_1 + a_2 d_2 P_2}{e_2 d_3 - e_3 d_2} \quad \ldots\ldots(7)$$

If L is not upon the joint at the summit, we find*

$$P = \frac{a_1 e_1 P_1 - a_2 e_2 P_2 + a_3 e_3 P_3}{e_2 d_3 - e_3 d_2} \quad \ldots(8)$$

$$Q = \frac{a_1 d_1 P_1 + a_2 d_2 P_2 - a_3 d_3 P_3}{e_2 d_3 - e_3 d_2} \quad \ldots(9)$$

$$q = h_1 - \frac{a_1 P_1 - g_1 P}{Q} \quad \ldots\ldots(10)$$

* Add (4) and (3) and call the sum eq. (13); also subtract (5) from (3). Place the values of Q equal to each other in this last eq. and eq. (13); reducing, bearing in mind that $d_3 - d_2 = d_3$, $e_2 - e_3 = e_1$, &c., we find P as in eq. (8). Substitute this value of P just found in eq. (11) and deduce Q, which gives eq. (9). Eqs. (6) and (7) are only particular cases of eqs. (8), (9) and (10) when $P_3 = 0$.

Example 1. Fig. 21 represents the same viaduct, before considered in Art. 8, with a load of 40 tons on 15 feet of length over divisions 2, 3 and 4, on one side of the arch only. Table 1 (Art. 8) refers to the right half of the arch: table 2 of the same article to the left side.

Let us pass a curve of pressures through the middle of the crown and through a point, on each springing joint, $\frac{1}{3}$ depth joint above its lower edge.

We find from the drawing and tables

$g_1 = g_2 = 25.6$,	$b_1 = b_2 = 10.75$	
$P_1 = 330$,	$p_1 = 15$,	$a_1 = 10.6$
$P_2 = 236$,	$p_2 = 16$,	$a_2 = 9.6$

From (6):

$$P = \frac{a_1 b_2 P_1 - a_2 b_1 P_2}{g_1 b_2 + b_1 g_2} = 24 \text{ cubic ft. of stone};$$

from (7):

$$Q = \frac{a_1 P_1 - g_1 P}{b_1} = 268 \text{ cubic ft. of stone};$$

From M, the middle of the crown joint, lay off downwards $\overline{MN} = P$, also $\overline{NH} = Q$ on the horizontal through N; $\overline{MH}$ will then represent the resultant on the crown joint in direction position and magnitude; and by combining it with the weight of each artificial voussoir and load, on each side of the crown, each acting through its centre of gravity, we evidently obtain the resultants on the various joints in direction, position and magnitude, and therefore can trace the curve of pressures. For example, to find the resultant on the third joint on the left side of the arch: draw a horizontal line through M and lay off on it the distance of the centre of gravity of the three first divisions, from M, which by Table 2 (Art. 8), column C, is found to be 8.8.

Draw a vertical through this point and from its point of intersection with $\overline{MH}$, lay off upwards the weight 159 (column S) of the three divisions in question.

From the upper extremity of this last line draw a line $\parallel$ and equal to $\overline{MH}$; completing the parallelogram of forces as per figure, the point where the resultant cuts joint 3 is the centre of pressure of that joint, and the resultant is given in magnitude, position and direction by the diagonal.

The construction for the other joints is the same.

The nearest approach of the curve of pressures to the extrados is on joint 2, of the left side of the arch, where it is only

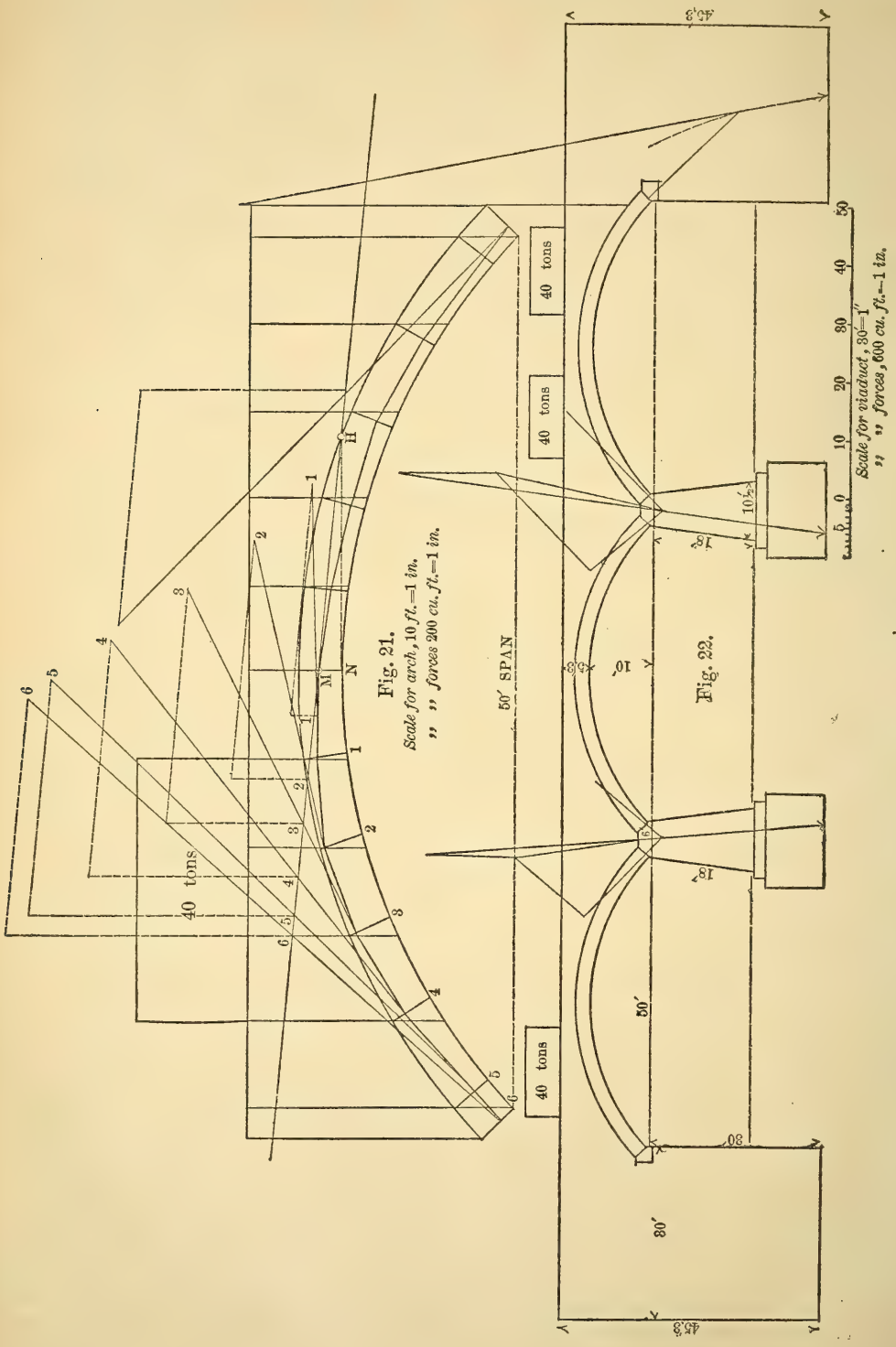


Fig. 21.

Scale for arch, 10 ft.=1 in.
" " forces 200 cu. ft.=1 in.

Fig. 22.

three tenths (.3) of a foot (on a large scale drawing it was found to be .35) from the edge. The nearest approach to the intrados is at joints 3, 4 and 5 on the right, being only about .7 to .75 from the edges at those joints. Hence if we desire the curve of pressures, with this load, to remain in the middle third of the present arch ring, we must increase its depth about .6 ft. making the arch stones 3.1 ft. in depth.

It will be interesting to compare some empirical formulæ with this result. Dr. Rankine gives * for the "depth of keystone for a single arch.

in feet $= \sqrt{\cdot 12 \times}$ radius at crown)"
$= \sqrt{.12 \times 36.25} = 2.1$.

Depth of keystone for an arch of a series, in feet $= \sqrt{.17 \times}$ radius at crown $= 2.5$.

Mr. J. C. Trautwine gives † for that span and rise 2.16 as the proper depth of keystone.

By interpolation from Dr. Scheffler's tables ‡ we find that he recommends in this case 3.5 ft. depth of keystone.

It must be remembered that when a locomotive passes rapidly over a bridge, that the principle of the least resistance can only apply approximately, as *it takes time* for molecular resistances to come into play; besides the shocks and concussions are the more damaging the smaller the bridge, hence while there is probably stability of the arch (Fig. 21) for a quiescent load of a 40-ton engine, it is not so certain for a moving load of that weight.

As the spandrels are not capable of exerting much resistance above joint 2, it seems that it would be advisable to increase the depth of keystone to three feet.

In fact while engineers have continued to increase the size of pieces in wood and iron bridges, as heavier engines were used, in some cases to double the size once used, yet they recommend for stone bridges the same depth of keystone that has been found to answer for road bridges built many years ago. We are indebted to Dr. Scheffler, now, for the means of completely investigating symmetrical or unsymmetrical arches, with any kind of loads, vertical or inclined, upon the hypothesis of incompressible voussoirs; besides we may be said at last to have got upon the right track of investigation as deduced from the principle of the least resistance; hence we should be no longer confined to purely empirical formulæ.

When we shall know the laws of elasticity, the theory may be regarded as complete for a statical load.

It looks probable, however, from a consideration of the experiments with the wooden arches, as well as cases in practice, that the theory for incompressible materials is not modified greatly; and it is more likely that severe shocks may have a greater influence in modifying that law, than the compressibility of the materials used. A considerable margin should always be left for these influences.

Example 2. A load of 13.3 tons was assumed on division, 3 on one side, and it was found that a curve of pressures could be drawn, for this eccentric load, within the inner third of the arch ring.

If the backing is raised higher, thus making the bridge weigh more, a rolling load will have less effect upon it; hence a less depth of keystone may be used. Other things the same, it is a simple question of economy, considering the approaches, whether to increase the height of surcharge above the arch ring, or the depth of the arch stones. The bridge considered could have the backing raised a foot higher with advantage.

Fig. 22 shows the effect of rolling loads in different positions, on the piers; the middle bay not being loaded but with its own weight, the end spans as per figure. The resultants at the springing joints we have before determined; combining the two on any pier with the weight of pier, according to the usual rule for three forces not intersecting in one point, we obtain the final resultants on the base of the piers. It is seen in Fig. 22, that in both cases, the resultant falls inside the base a sufficient quantity for a rock foundation, though probably not for a soft one.

It is seen from the figure that the 40 tons on both sides produce a more hurtful effect on the pier than a 40 ton load on one side only.

By combining the weight of abutment with the thrust on it, we find that the centre of pressure on the foundation course is sufficiently within the limits for most cases in practice.

The dotted line in the abutment gives the centres of pressure of all the forces act-

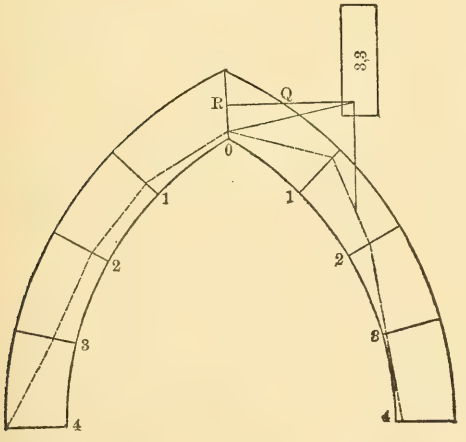
* "Civil Engineering," Art 290.
† "Engineer's Pocket-book," p 345.
‡ "Traite de la Stabilité," pp. 257, 277.

ing on each joint for the joints in question. For example, to find where this centre of pressure is on the springing line, produced, we combine the inclined resultant on the arch joint at the spring ng with the weight of the abutment above the springing line, acting through its centre of gravity. This resultant makes an angle with the vertical of only 23°, hence sliding on the springing course is not to be feared, if the abutment is solidly built. This centre of pressure must not be confounded with the points of greatest intensity of stress which includes the springing, but cannot be farther traced in the abutment composed of a number of stones.

We have considered the stability of this common form of viaduct under every point of view necessary in practice, and in the same manner can other forms of arch be investigated.

If in any arch the first trial curve passes outside the proper limits, mark the joint limits opposite the points of greatest departure and pass a curve through three points

Fig. 23.



thus found by the use of eqs. (8), (9) and (10). If the arch has stability at all, it will generally be found that this last curve drawn will remain in the proper limits; otherwise repeat the operation.

It would lead us too far to consider inclined forces, which are fully discussed by Dr. Scheffler and offer but little difficulty.

First Experiment. The Gothic arch given by Fig. 11 will now be considered with an unsymmetrical load. A stout needle was thrust into the second voussoir from the crown on the right side, in the direction of a vertical through its centre of gravity, as represented in Fig. 23. With a weight of 3.3 vs. on the top of the needle, the arch balanced; opening at summit and lower edge of joint 1 on the right. The voussoir to which the weight was added would have slid if pins had not been thrust into the edges of its joints, thus supplying a force analogous to friction, though not interfering at all with rotation.

We now form the following tables; the first being condensed from the one referring to Exp. 3, in Art. 9:

LEFT SIDE.

	S	C
1	1	1.70
2	2	3.19
3	3	4.39
4	4	5.26

RIGHT SIDE.

	S		M	S	M	
1	1.	1.7	1.70	1.	1.70	1.70
2	4.3	4.68	20.12	5.3	21.82	4.12
3	6.1.	[illegible]	6.79	6.3	28.61	4.54
4	1	[illegible]	7.88	7.3	36.49	5.
	7.3		36.49			

As the crown joint bore near the lower edge and the first joint on the right near its upper edge; try a curve of pressures passing .1 from those edges and 1 from the extrados on joint 4 on the left.

We find

$$g_1 = 8.9 \qquad g_2 = 3.9$$
$$a_1 = 3.64 \qquad a_2 = 2.2$$
$$b_1 = 12.2 \qquad b_2 = 0.65$$
$$P_1 = 4. \qquad P_2 = 1.0$$

By Eqs. (6) and (7) we find

$$P = \frac{3.64\times.65\times4 - 2.2\times12.2}{8.9\times.65 + 2.2\times3.9} = -.326$$

$$Q = \frac{3.64\times4 + 8.9\times.326}{12.2} = 1.43$$

P. is here minus, hence we lay it off upwards, then measuring Q to the right we get the resultant S at the crown from which the line of pressures may be drawn as in Example 1 of this article.

The line of pressures drawn with these values of P and Q passes .36 from the lower edge of joint 3 on the right. It should pass the same distance from the edges at joint 4 on the left, the crown and joints 1 and 3 on the right, to correspond to the maximum and the minimum of the thrust, hence this curve just found is not the true one.

In two more trials, it was found that the true line of pressures passed about .18 from the edges just mentioned, as drawn in Fig. 23.

Although the characteristics of the minimum and the maximum of the thrust are not demonstrated, the reader will perceive that there should be stability in this case as the line of pressures is inside the proper limits. The lower edge of the crown joint was imperfect, being the only imperfect edge in the arch, and this may account for the line of pressures retreating farther in the arch than for a load on the summit as before considered.

The thrust on joint 1, on the right, was inclined at an angle of 15° to the normal to that joint, which accounts for the sliding, as the joints were planed and across the grain.

2nd Experiment.—The segmented arch, Fig. 13 was next tried with the eccentric load.

A short needle was thrust in voussoir 2 on the left, in the direction of the vertical through its centre of gravity, as shown in Fig. 24: the arch balanced with 5.4 voussoirs on the top of this needle.

We form the following tables:

RIGHT SIDE.

	s	m	S	M	C
1	1	2 03	1	2.03	2.03
2	1	5.90	2	7 93	3.96
3	1	9.38	3	17·31	5.77
4	1	12.11	4	2	

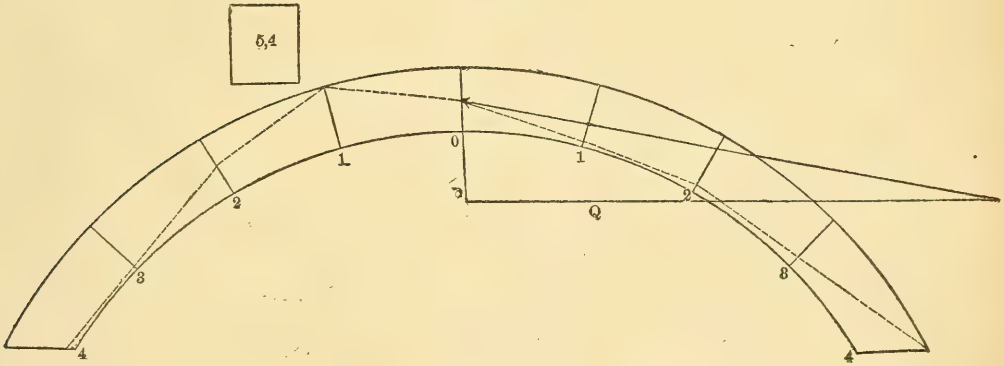
4 25.42

LEFT SIDE.

	S	M	S	M	C
1	1.	2.03	1.	2.03	2.03
2	6.4	37.76	7.4	39.79	5.38
3	1.	9.38	8.4	49.17	5.85
4	1.	12.11	9.4	61.28	6.52

9.4 61.28

FIG. 24.



The voussoir on which the weight was placed would have slid along its joints, but for pins being thrust into its edges in a manner that did not interfere with rotation.

The arch flew out at joint 2 on the right, hence a curve of pressures was tried passing .2 from the inner edge of this joint as also the middle of the crown, and .2 from the intrados at joint 4 on the left. This curve indicated the true curve more closely. A curve of pressures was next tried passing .2 distant from the intrados at joint 4 on the left and the extradosal edge at joints 1 on the left and 4 on the right. In this case we find from the drawing and the tables:

$g_1 = 12.32$	$g_3 = 4.14$	$g_2 = 14.17$
$a_1 = 5.80$	$a_3 = 2.21$	$a_2 = 6.8$
$h_1 = 9.$	$h_3 = 0.8$	$h_2 = 9.$
$P_1 = 9.4$	$P_3 = 1.0$	$P_2 = 4.$
$e_1 = 8.2$	$e_3 = 0$	$e_2 = 8.2$
$d_1 = 18.41$	$d_3 = 26.49$	$d_2 = 8.08$

From equations (8), (9) and (10) we obtain

$$P = \frac{5.8\times8.2\times9.4 - 6.8\times8.2\times4 + 2.21\times0\times1}{8.2\times26.49} = 1.03$$

$$Q = \frac{5.8\times18.41\times9.4 + 6.8\times8.08\times4 - 2.21\times26.49}{8.2\times26.49 - 0} = 5.36$$

$$q = 9 - \frac{5.8\times9.4 - 12.32\times1.03}{5.36} = 1.2$$

On constructing the curve of pressures with this data, we find that it passes .15 from the intrados at joint 2 on the right and of course .2 distant from the edges at joints 4, 1 and 4, as assumed; hence the

true curve will probably pass about .18 from these edges. This is nearly (.03 difference) what we obtained, for the limits from the edges of the line of pressures in the 11th Exp., Fig. 13. The thrust on joint 1 on the left is inclined 16°.5 to the normal to the joint, nearly what we found before. This sliding in this and the last experiment only occurred just before the balancing weight was applied; the line of pressures travelling down the crown joint as the weight was increased, until finally the direction of the pressure on joint 1 exceeded the complement of the angle of friction.

After patiently investigating all the preceding experiments, we can not but conclude that Dr. Scheffler's theory of the curve of pressures, viz., that it corresponds to the minimum thrust that is consistent with the physical properties of the materials, is proved and beautifully illustrated by them.

13. Analytical formulas for arches are founded upon this hypothesis*: that a curve drawn tangent to the resultant pressures on the joints, coincides, for all purposes of testing the stability of the arch, with the line of pressures of Dr. Scheffler.

Now it is evident in the first place that the above hypothesis can only be proved by innumerable graphic constructions; hence the latter method is the real foundation of the first, if the hypothesis is shown to be correct by the constructions. In the second place, the hypothesis is near enough in some cases as *e. g.*, our viaduct, Figs. 9, 10 and 21, but that it is not so in other cases may be seen by drawing the tangent curve to the resultants, in the case of the oval of the Neuilly bridge (Scheffler Fig. II.) about joints 6 and 7; the pointed arch, Fig. IV., at joints 4 and 5; as also the experiments with the Gothic arches of this article, where the tangent curve does not cut the springing joints at the true centres of pressure, and hence the true line of pressures would not have been given by the analytical formulas. In fact an arch may be perfectly stable, when this tangent curve passes outside of the arch ring. Dr. Scheffler handles this and other theories with gloves off. The graphic method is so simple, and so little liable to error, compared with the other, that constructors will probably prefer it in testing the stability of an arch. It must not be forgotten, though, that analysis has afforded us the proper form of arch for many particular kinds of load; though the graphic method will effect the same thing by assuming our arch, drawing a line of pressures through the middle of the crown and abutment joints and then taking this line for the centre of the arch. A second approximation will rarely be needed if the first form of arch is chosen with some discretion.

The graphic method is *general* and applies to any conceivable arch, loaded in any conceivable way, symmetrically or otherwise.

The theory of groined and cloistered arches, as well as domes, is treated by Dr. Scheffler, making use of the principle of the least resistance to ascertain their stability.

*Rankine's Civil Engineering, Art. 280.

COMBINATIOM BRIDGES FOR RAILROADS.

By J. O. PATTERSON, C. E.

Written for Van Nostrand's Magazine.

In advocating the adaptability and economy of the use of Combination Bridges on railways, the writer has been frequently met by the assertion of two objectionable features.

First.—That the difference of expansion from change of temperature in wood and iron causes such a serious loss of camber in hot weather that the bridge is in danger of falling below the horizontal line.

Second.—That the difference in cost between a bridge entirely constructed of iron and one of wood and iron combined is not sufficient to warrant the sacrifice of permanency due the iron structure.

Convinced by some experience of the practical economy and efficiency of combination bridges, the author has been led to examine the ground on which these alleged objections rest.

In regard to the first: the loss of camber, it is obvious that the expansion or contraction of the web members of a truss can not affect the camber, except to the infinitesimal

extent due the changes of depth of truss from that cause. Therefore we have only to consider the elongation of the bottom chord as tending to allow the bridge to sag. A moment's consideration of the nature of a truss shows this to be true. We have two chords taking the horizontal stresses and a system of triangles which take the place of the web of a solid girder, transmit the shearing stress to the abutments and maintain the chords fixed in the same relative position. Now if we increase the length of one of these chords, or rather spread each of the triangles of the web a little at the top, we force the truss to take a curved form. Because the long chord being prevented by the web from sliding on the short one they necessarily become parts of concentric circles, thus compensating for their difference of length. In a parabolic truss the want of parallelism in the chords does not affect the principle, but the increase of length in each panel would not be uniform but proportional to the depth of truss. Between 8000 and 9000 feet is the ordinary radius of the camber curve.

In order to ascertain the amount of variation of length which is likely to occur in the bottom chord, we will assume 150 degrees (*i. e.* from −30 deg. to x120 deg.) to be the maximum range of temperature for the section of country most actively engaged in the construction of railroads.

The expansion of wrought iron due 150 deg. increase of heat as given in the text books would equal 0.001 of the length of any bar of that material, but it is but fair to suppose that the drilling of the eye bars of a bridge chord (which determines their length) is done with the body of the bars at an average temperature of say 60 deg., therefore it is not the extreme variation of temperature which should determine the loss of camber, but the difference between that at which the bars are formed and the maximum.

However, as the top wooden chord is shortened by stress to a small extent, in the following calculations, we will consider the maximum range of 0.001, the length as affecting the bridge.

Taking, for example, a truss of 199′ 6″ clear span, and 24 ft. deep, say 14 panels of 14′ 3″ each on the Howe plan, with a camber of 7 in. Each panel of the top chord would be increased in length $\frac{6}{10}$ of an inch, and as there are 12 panels (the end posts and counter being omitted) the total increase in length of upper chord would be 7 2 in. The greatest possible longitudinal expansion of the lower chord equal 199′ 6″ $\times 0.001 = 2\frac{37}{100}$ in. $- 7.2'' - 2.37'' = 4.83''$ $= 4\frac{3}{4}$ in. camber remaining in bridge. The deflection under full moving load should be between $1\frac{1}{4}$ and $1\frac{1}{2}$ in., consequently there will remain $3\frac{1}{4}$ in. crown in the truss under the most unfavorable circumstances, which is certainly an ample margin for safety. As the camber and deflection are both proportionate to the span, there would be a proportionate margin in any length of truss.

The contraction of the chord in winter would simply have an opposite effect—increased camber; and while the bridge does not drop below the horizontal line and one end is free to move, can cause no excessive stress.

As regards the second objection, it seems to me that so long as the interest on the excess of cost of an iron over a combination bridge remains more than sufficient to pay for renewals of the latter, the former remains the most costly, or, to state it more conveniently, let c=first cost of combination bridge, and x=same for iron bridge, r cost of renewal in percentage per annum on first cost, and r'=legal or average rate of interest. Then we will say an iron bridge will only be economical when $x < \frac{C(r'+r)}{r'}$ In this case the greater original cost of the iron bridge may fairly be said to offset the inconvenience of the periodic renewals of the combination.

As an example, compare the cost of trusses 160 ft. in length, constructed on the two systems.

Such a bridge on combination plan, with timber planed to facilitate painting, and top chords housed or covered, can be built by any reliable firm, at present prices of material, for $40 per lineal foot.

We will suppose, to be on the side of safety, that the bridge will only be reliable for 10 years. An iron bridge by the same builder would not cost less than $70 per lineal foot, *vide* bids on the 25 Erie Railway bridges.

The two trusses will then stand as follows:

IRON.

First cost	$11,200
Interest 10 years at 6 per cent	6,720
Total cost at end of ten years	$17,92

COMBINATION.	
First cost	$6,400
Interest 10 years at 6 per cent.	3,840
2,000 ft. beam pine timber for renewals at $25	800
Labor on renewals at $5 per foot.	800
Total cost at end of ten years.	$11,840

The charge of $1,600 for renewals is= 0.025 per cent. per annum on original cost of combination truss, and applying our formula we have $\frac{C(r' + r)}{r'} = x =$ £9,066,66 and under this price we must build the iron bridge to obtain for it the merit of economy.

In the renewal of the combination bridge only the cost of timber has been figured, as the ironwork after ten years in it would certainly be as valuable as iron after the same service in the other truss.

GENERAL REMARKS.

If the end braces or posts of a combination bridge are of iron (about $1,00 per lin. ft. of truss will pay for Phœnix columns at end) and the top chord of timbers extending over not more than two panels, then the entire wooden portion of truss may be renewed piece by piece, without the employment of any false work.

A properly designed truss of wood and iron once carefully adjusted should require no more attention than one of iron. In fact, in the post combination no adjustment is possible, nor has it been found necessary. A change of length of probably $\frac{1}{64}$ of an inch in the vertical rods, or $\frac{1}{32}$ in the long diagonal with double intersection, can hardly be expected to disarrange the relation of parts of a truss to any hurtful extent.

Of the many forms of truss which have been adapted to the combination principle, the lightest, most elegant, and suitable of all seems to have been entirely neglected. I allude to the *inverted bowstring;* for a deck bridge nothing can be more simple and effective, and it is as readily adapted to a through bridge as the "Fink" or "Bollman." By varying the length of panel the eye bars may be kept of uniform length, the diagonal bracing necessary is extremely light, the posts have but a panel load to carry except towards the centre of span between the points at which the stresses change sign under a moving load where there is a slight excess to be borne. The top chord being subject to the maximum stress from end to end, would occasion serious loss of economy if of metal, but being timber, the fact is immaterial (as all attempts to reduce the amount of timber towards the ends of chords of that material to theoretic requirements have resulted in an expense of framing greater than the saving in timber), and furthermore, if there is any position about a bridge in which a cast-iron strut may be used with safety and economy, it is as a post in this style of truss. All these points considered, I think the inverted bowstring deserves a trial, at least.

Of the permanency of our iron bridges nothing has been said in this paper, as that question has been frequently raised and discussed; future experience alone will decide it; that some of them will fail in parts exposed to moisture but inaccessible to the paintbrush, is more than probable.

IS 772 FOOT-POUNDS THE TRUE DYNAMICAL EQUIVALENT OF ONE THERMAL UNIT.

By E. A. JACK, C. E.

Written for "Van Nostrand's Magazine."

Latent heat has been defined as the quantity of heat which disappears in producing changes other than elevation of temperature. Let us suppose the change to be that of volume, and convert it into foot pounds of energy, with air for an example.

The volume of 1 lb. of air at 32 deg. Fah., is 12.387 cubic feet, and it expands 0.0020276 of its volume, or 0.025 cubic feet for an increase in temperature of 1 deg. Fah., and in so doing exerts $2116.3 \times 0.025 = 5.29075$ foot pounds of energy.

Now the specific heat of air at constant pressure ($c\,p$)=0.238 of a thermal unit, and at constant volume ($c\,v$)=0.169 of a thermal unit. Hence $0.238 - 0.169 = 0.069$ is the latent heat of expansion or fraction of a thermal unit that has been converted into work of expansion.

And $\frac{52.9075}{0.069} = 766.8$ is the dynamical equivalent of one thermal unit for this process. This, substracted from Joule's equivalent, leaves $772 - 766.8 = 5.2$ foot-pounds, which may have been expended in producing work other than that of expansion.

LOCOMOTIVES FOR ASCENDING STEEP INCLINES WITH SHARP CURVES.

(Continued from October No., page 313.)

Every departure from this in an ascending direction, operates against the advancing power of the locomotive in two ways, viz., by diminishing the surface adhesion of the wheels and rails, and, on the other hand, proportionally adding to the weight to be raised or drawn up the incline. While the surface adhesion, on which the ability of the locomotive to advance depends, is diminished, the load it has to contend against is increased by bringing the force of gravity to act upon it, tending to drag it down the incline. The preceding observations embody the physical facts or principles, from which the best practical means of enabling locomotive trains to ascend inclines are to be educed. It is not *primarily* a question respecting increasing the power of a locomotive to enable it to draw a greater weight up an incline than on a level; for no amount of power can avail to effect the desired object, if the hold of the driving wheels on the rails be inadequate to keep the locomotive advancing, and hence it becomes one simply as to the best means of supplementing or compensating the diminished adhesion of the driving wheels on an incline, subjected at the same time, in its reduced state, to the direct opposing force of gravity.

To compensate for this loss of surface adhesion on inclines, recourse is generally had to coupling all the wheels, or as many as are practicable, to the driving wheels, or, in other words, to make use of the entire weight of the locomotive for adhesion. But it does not fulfil this end without incurring a disadvantage of a different kind, for increasing the number of coupled wheels of a locomotive beyond a certain limited extent, is open to serious objections, on account of the lateral frictional resistance encountered on curves by a series of coupled wheels connected in a longitudinal direction by rigid bars susceptible of little or no lateral motion.

The remedy to be sought, therefore, is to obtain an equivalent amount of surface adhesion by some other method which is free from this objection, and the design of these observations is to suggest one way in which this may be accomplished.

The framework of the locomotive and tender (which is rigid throughout) is supported on three axles so placed as to have as nearly as possible an equal pressure on each axle. The centre axle is of sufficient length to allow of transverse play through the axle boxes, and thus accommodate itself to curves of any degree of sharpness. The two end axles have not means for transverse play as the middle one, but have the boxes in which they run so arranged as to allow the axles always to point to the centre of the curve or curves on which the locomotive is travelling, with an arrangement of springs to cause them to return to their normal position on arriving at a straight portion of the line. The centre axle also has a certain amount of lateral play in its axle-box, but not so much as the two end ones. On each of these axles are two pair of wheels, one pair at each end placed close to each other, the wheels running on a pair of double rails. The outside wheels are the ordinary flanged ones now in use, while the inside pair have a concave surface running on corresponding convex rails. The motive power is obtained by three pair of cylinders, one pair for each axle. Each pair of cylinders are fitted on an independent framework resting on the axle, and supported at each end by wrought iron plates, between which the framework is capable of moving on friction rollers, etc., when force is exerted on it by the axles on the wheels entering upon curves, and thereby causing the pistons to act normally to the axles under all conditions.

So that we have, as it were, three independent locomotives with a boiler, tender, tank, etc., in common. Of course to supply sufficient steam for so many cylinders the locomotive must be of large dimensions; but that is no objection, as it is found that 50, 60, or even 80 tons of adhesion weight are required now-a-days for working cheaply constructed lines with heavy gradients and sharp curves.

In order to obtain as equal a pressure as possible on each axle, the boiler and

furnace are placed in the centre of the frame, and a coal bunker and water tank is placed at the ends. But these are mere matters of detail, and, of course, are subject to modification, depending on the nature and size of the locomotive. But the two great principles to be borne in mind are—1st, that the entire weight of the locomotive, &c., shall be available for adhesion; and 2nd, that there shall be no rigid couplings. As there are a double line of rails, the best gauge would be 5 feet 6 inches, which is the one used on the Indian Railways, and which is, if I mistake not, now considered to be the best, taking both economy of working and safety in travelling into account.

There are four points to be urged in favor of the adoption of a double pair of wheels on each axle and corresponding double rails:—

1st.—That the great pressure on the rails is relieved by doubling the points of support, which becomes a matter of the gravest importance when locomotives of upwards of 60 tons are used.

2d.—That the lateral frictional resistance resulting from the use of rigid coupling rods is got rid of, and

3d.—That additional safety and steadiness are obtained in running round sharp curves.

4th.—The surface adhesion is increased enormously, since the surface of the inner wheels and rails are made to fit exactly, and we have two surfaces in contact during the revolution of the wheels on the rails, instead of only two lines, which is the case with the coned wheels.

Against these advantages is to be balanced the additional outlay in the construction of the line; but, as the deterioration and wearing away of the rails is chiefly, if not alogether, caused by the driving wheels of a locomotive, these double rails should last double the time that a single rail does, supposing the same number of driving wheels run on the double rails as run on the single, so that the only loss is the interest of the extra outlay.

But what is it compared to the enormous savings effected by having steep gradients and sharp curves in lieu of expensive tunnels and viaducts. On curves allowance is made for lateral friction, by reducing the cross section of the inside rails.

I have still another plan to propose, but which is more suited for moderate gradients, such as are to be found at home, and which is applicable to the present system of locomotive trains. It consists in converting into assistant locomotives, worked by the pressure of the atmosphere, the tender, and any other vans or carriages of the train that may be deemed suitable for this purpose. The tender and carriages selected for this purpose would require to be furnished with a pair of driving wheels fitted up with the usual pistons and cylinders, having the usual apparatus of valves opening alternately to the atmosphere and to an eduction or vacuum tube. The latter to be carried below the middle of the connected carriages, having at the coupling of each carriage a flexible or yielding point, to adapt it to their independent movements, and terminating in exhausting cylinders, placed in the primary locomotive, and worked by the power of its engine, in addition to working its own driving wheels.

Without entering into further detail, it may be observed that the practical difficulties connected with this arrangement seem to be chiefly of a mechanical kind, relating to the joints of the vacuum tube, such as rendering them capable of being easily connected and disconnected, preserving their air-tight function and flexibility, and insuring them, under ordinary circumstances from being liable to injurious extension or compression amid the irregular movements of a train of loosely connected carriages having a certain amount of play between each. But in the present advanced state of the mechanical arts it cannot for a moment be regarded as being of a very formidable character.

As the pressure on any part of the atmospheric apparatus can never, under any circumstances, on account of imperfect vacuum, come up to 15 lbs. per square inch, there will be the less difficulty in making the joints at once sufficiently strong and flexible; while, for the same reason, general lightness may be consulted in the construction of every part of the arrangement.

The advantage of the plan just described is, that it permits the extension of locomotive power through the medium of atmospheric pressure, to any portion of

a train, thus rendering it assistant in the work of propulsion. But if it were desired not to carry it further than the tender, the most obvious and better way would be, instead of employing atmospheric pressure, to connect the tender by a steam pipe, having a strong flexible joint at the coupling, with the boiler of the locomotive for the supply of steam power to work the machinery of the tender.

Since this part of my paper was written in December 1862, Mr. Sturrock, the Superintendent of the Locomotive Department of the Great Northern Railway, has taken out a patent for working the tender by steam obtained from the boiler of the locomotive, and the results obtained by this improvement are exceedingly good. Thirty-three per cent. of excess of load, and 50 per cent. if the furnace is improved, has to be drawn by locomotives with their tenders thus fitted up.

With regard to the proposition for obtaining additional motive power by means of atmospheric pressure, I would wish to state that I bring it forward more as a suggestion than as a carefully worked out problem; of its practicability I have no doubt, provided that the exhaust is capable of maintaining a sufficient vacuum.

ON MORTAR.*

From "The Engineer."

In buildings and structures mortar is employed as the agent for causing the stones, bricks and other materials used in construction to adhere together, also to fill any crevices and irregularities in bedding them. Its use for these purposes is of the remotest antiquity; we read of slime being used in building the Tower of Babel, and asphalte in the construction of the walls of Babylon, and it is found from an analysis of mortar taken from the pyramids of Cheops that the Egptians employed lime and sand almost in exactly the same proportions that we now do; and even the careful directions given by Vitruvius in the fifteenth century were carried out until the more modern researches of Vicat.

The remarks in this paper will be confined to the treatment of mortar formed by the admixture of lime with sand and other ingredients; and as it is the author's opinion that a few facts obtained from actual practice are of much more value than any number of individual opinions which he might offer, he will, by the kind permission of Mr. George Fosbery Lyster,—member of this institution, and Engineer-in-chief to the Mersey Docks and Harbor Board—endeavor to base this paper on data obtained while studying the method carried out by that gentleman at Liverpool.

The limestone which has been here employed for the past forty years in carrying out the most extensive hydraulic works, is obtained from quarries situate in the Halkin Mountains, Flintshire, and is that ordinarily used in Lancashire, Cheshire, the West of England and Wales.

It is found from an analysis by Dr. Musprat of Liverpool to be composed of 75 per cent. of substances soluble in nitric and hydro-chloric acids, and 25 per cent. of those insoluble. The soluble substances are:—Carbonate of lime, 72.0 per cent.; carbonate of magnesia, 1.3 per cent.; proto-carbonate of iron, 1.0 per cent.; sulphide of iron, 1.0 per cent.; alkalies, 0.7 per cent. Those insoluble are:—Silicic acid, 20.0 per cent.; alumina, 3.5 per cent.; sesquioxide of iron, &c., 1.1 per cent.; water and carbonaceous matter, 0.4 per cent.

The limestone, in order to expel carbonic acid, is calcined in kilns, on plan oval 18 by 12 feet, and 20 feet in height from the fire-bars, which dimensions give a capacity of 3400 cubic feet. The interior is lined with fire-bricks, and the usual dome top is here dispensed with; three such kilns are built into one rectangular construction of rubble work, each of which is provided with a hoist for the purpose of lifting the limestone and fuel to the summit of the structure when filling the kiln. The charging is done in the following manner:—A few shavings are placed on the fire-bars, upon which is spread a layer of coke about six inches in thickness, limestone is then thrown in until a thickness

* Read before the Edinburgh and Leith Institution of Engineers, by Mr. Graham Smith.

of 1 foot, 10 inches or 2 feet is attained. This is followed by another layer of coke, and so on alternate layers of coke and stone until the top of the kiln is reached, the layers of stone gradually increasing in thickness to 2 feet 6 inches at the top, with the exception of the uppermost, which, owing to its being exposed to the atmosphere, is made only 9 or 12 inches. When completely charged, the shavings are lighted and the whole allowed to burn for six or seven days, as experience may direct, after which time not a trace of the coke is perceptible. The fire-bars are then withdrawn and the burnt lime raked out of the aperture thus formed on to the floor of an adjoining shed, where it is slaked with water, and produces a lime of moderate whiteness, after which, owing to the irregular size of the stones put into the kiln, it is occasionally found that some of the stones are not sufficiently burnt. When this happens they are picked out and reburnt, but by care in having the stones reduced to about the same size in the first instance this is of seldom occurence.

In burning lime care must always be taken not to reach too high a temperature, as, owing to the fluxing properties of the lime, the silica and alumina would combine and form a species of glass. The stones should also be broken to a comparatively small size, in order that the heat may more readily penetrate to their interior, and thus effect a saving in fuel. The amount of limestone put into the kiln is 113 tons or 1930 bushels, and the requisite amount of coke is 14½ tons. This produces 75 tons or 1170 bushels of burnt lime, which, with 15½ tons of water necessary to slake this quantity, yields 98 tons of slaked lime or 3411 bushels. From these quantities it will be seen that the slaked lime has nearly three times the volume of the burnt lime which produced it, and that its weight is nearly 9 per cent. more than that of the burnt lime and water together. Limestones, when calcined, produce rich limes, hydraulic limes, and cements. Rich limes are produced from stones consisting almost wholly of carbonate of lime, such as chalk. They slake freely, and during this process augment from two and a-half to three and a-half times in volume. These harden slowly in air and not at all in water, and the mortar formed from them is liable to be affected by changes in the atmosphere. Hydraulic lime is obtained from stones containing 15 per cent. to 30 per cent. of silicates and sometimes magnesia. These do not slake freely, give off little heat, and will harden slowly under water. Some stones, containing 40 per cent. to 60 per cent. of silicates, produce cements which do not slake, but which, when ground and mixed with water, will set in air or water in a few minutes. The agency to which mortars owe their power of setting is not generally understood, but it is commonly considered that this action in rich limes is due to the evaporation of water and the gradual absorption of carbonic acid from the atmosphere, thus forming a crystallized carbonate of lime. In hydraulic limes it is believed that the setting takes place from a chemical union of the lime with silica and alumina, thus forming an insoluble crystallized double silicate, without which mortars, placed in positions where air cannot penetrate, would never harden. The author therefore considers that the quantity of carbonic acid gas in the atmosphere being limited will to some extent account for the slow setting of rich limes; and as the atmosphere cannot penetrate to a great extent into thick walls and masses of concrete, it would be unadvisable to use for these purposes anything but hydraulic limes or cement, for the hardening of which the influence of the atmosphere is comparatively unimportant. From the analysis of the Halkin limestone, it will be seen that the components producing setting and indurating under water exist to the extent of 25 per cent., and being evenly distributed through its entire mass, produce a mortar most favorable to the formation of an insoluble crystallized double silicate. To obtain good mortar, as much depends on the character of the ingredients and the manner of mixing them as on the goodness of the lime itself. It does not necessarily follow that because a lime is good that the quality of the mortar will be good also. The best lime ever burnt would be spoiled by the custom common among some builders—to mix with it alluvial soil and rubbish taken from the foundation pits of intended buildings. The sand should be hard, sharp, gritty, and, for engineering purposes, not too fine; it should be perfectly free from all organic matter, and with no particular smell. Good sand for mortar may be rubbed between the hands without soiling them. The

water should also be free from all organic matter, and on this account should never be taken from stagnant ponds. The presence of salt in sand and water is not found to impair the ultimate strength of most mortars; nevertheless, it causes the work to "nitrate," or, as it is commonly termed, "saltpetre," which consists of white frothy blotches appearing on the face of the structure. It also renders the mortar liable to moisture, and for these reasons should never be present in mortar intended for architectural purposes, although for dock walls and sea-works it may generally be used with advantage and economy.

Sand is used to increase the resistance of mortar to crushing, to lessen the amount of skrinking, and to reduce the bulk of the most costly material, lime. Water is the agent by which a combination is effected, and, as sand does not increase in volume by moisture, it necessarily follows that no more of the aqueous element should be employed than is absolutely necessary to fill the interstices between the sand, and render the whole into a paste convenient for use, and the greater strictness with which this is adhered to, the more compact and durable will be the mortar. The mortar made from the Halkin lime is mostly employed on the Mersey Dock Estate in the construction of dock and river walls, for which purposes it is always mixed with salt water and sea-sand. The lime, within one to four days after being slaked, is taken to the mortar mills, which are cast iron circular pans 7 ft. in diameter, caused to revolve by suitable spur gearing at the rate of 20 revolutions a minute. In each pan are placed two rolling stones 4 ft. 6 in. in diameter. There are 14 such mills to each set of three kilns, which are driven by an engine of 50 indicated horse power, and it is generally calculated that one mill requires $3\frac{1}{2}$ horse power to work it, as the mills are seldom all working at the same time. The engine before mentioned is found adequate to drive the mills, lift the stone and fuel to the top of the kilns, and to pump from an adjacent dock the required quantity of water for mixing the mortar. The pans of the mills are provided with false bottoms, in order that they may be replaced when worn out, the average life of these being about three months. In mixing the mortar the lime is first ground in the mills in a dry state for three minutes, the sand is then added, and after five minutes from the commencement the water is turned on, and as the necessary quantity is gauged by the tap, it is allowed to run the whole time, which, for the ordinary mortar, is about 30 minutes; the quantity made at each mill in this time is a quarter of a cubic yard. In some cases the amount is actually measured in order to ascertain if the men are making their full quantity. One man has to carry from an adjoining shed sufficient lime, sand and ashes to make five cubic yards of mortar in a day, for which he is paid 3s. 6d. The ordinary mortar used in the construction of rubble masonry for dock walls is mixed by volume in the following proportions: One slaked lime, two parts sand and one-third of a part smithy ashes. And the proportions for that used in brickwork are: One slaked lime, one sand and one smithy ashes. For the sake of convenience, in laying before you the experimental results obtained by these compositions, the author will term them respectively "masons' mortar" and "bricklayers' mortar." In practice the ingredients are not measured, as it is found that three average spades of lime, sand or ashes, are equivalent to one bushel. The mode of testing pursued was as follows: Bricks, the quality of which will be described in each individual case, were accurately cut to $4\frac{1}{4}$ in. in width; these were in all cases thoroughly wetted, and bedded crosways, with a mortar joint $\frac{5}{16}$ in. thick and $4\frac{1}{4}$ in. by $4\frac{1}{4}$ in., giving a testing area of 18 sq. in. On the time arriving for testing, which, unless otherwise mentioned, was in every instance 168 days, or six lunar months, stirrups were passed round the ends of the bricks, two of these were attached to a beam, and on the remaining two was hung a bucket, into which perfectly dry sand was allowed to run from a hopper, the door of which was immediately closed when the joint parted; the bucket and sand were then weighed, and this was taken to be the breaking weight of the specimen. In order to ascertain the difference which would exist in practice from the employment of bricks of various texture, two qualities were experimented upon, namely, common bricks, similar although slightly harder than those known about London as "ordinary stocks," and fire-bricks, very hard and much the same as Staffordshire blue bricks. The "mason's mortar," with common bricks, broke with 496 lbs, with fire-bricks, 433 lbs. The "bricklayer's mortar," with common bricks, 610 lbs., with fire-bricks, 516 lbs. These are the average results of

three experiments in each instance, from which it would appear that soft porous bricks are preferable for work subjected in any way to a tensile strain. It being the author's impression that mortar when used in a structure would bear a greater test, owing to the compression caused by the weight of the superincumbent mass, some results were obtained by subjecting the samples, twenty-four hours after being bedded, to a pressure of 56 lbs., and following this up with an additional 56 lbs. every day, until 4 cwt. was placed upon each. The "mason's mortar" under these conditions, with common bricks, broke with 683 lbs.; with fire-bricks, 403 lbs. The "bricklayer's mortar," with common bricks, 372 lbs., with fire-bricks, 423 lbs. These are not average results, one experiment only having been made with each. The first instance is the only case in which the author's theory holds good, the remaining three cases being considerably below the respective averages of 433,610 lbs. before mentioned. This may be accounted for, as the author fears that in placing on the weights the mortar was disturbed after having partially set, in which case it will never bind together a second time. In the case of mortar remixed with water six days after the first mixing, it was found that with common bricks the "mason's mortar" broke with 432 lbs., against 496 lbs., obtained with the same mortar when first mixed; the "bricklayer's mortar" broke with 440 lbs., against 610 lbs, the advantage is thus shown of using mortar when first mixed.

The importance of the admixture of ashes with mortar to be atmospherically dried will be shown by the following results:—The bricklayer's mortar with common bricks after a lapse of eighty-four days broke with 570 lbs.; where sand was substituted in the place of ashes, that is, when the proportions were one slaked lime, two sand and no ashes, it only required 257 lbs. to tear assunder the bricks. These are the averages of three experiments. This is, no doubt, attributable to the ashes being porous; they thus allow greater facilities for the absorption of carbonic acid from the atmosphere. By testing with a Michell's lever cement testing machine, one of which is now before you, brickettes having a testing section of $1\frac{1}{2}$ by $1\frac{1}{2}$=2.25 square inches, the average result of three experiments was found to be 248 lbs., which will compare very favorably with the results obtained by Mr. Grant with Portland cement mixed in the proportion of three of sand to one of cement, which broke with an average of 270 lbs. From the foregoing it will be seen that nothing like these high results can be depended upon in actual practice, as the maximum breaking weight with bricks and mortar was 780 lbs., or 43.3 lbs. to the square inch, against 110 lbs., obtained by breaking brickettes. Although no experimental tests have been made with this mortar of any great age, still, from the pulling down of old work it may with confidence be asserted that it fully complies with the old Scotch rhyme:—

> "When a hundred years are past and gane,
> Then good mortar grows into stane."

On the Mersey Dock estate every stone and brick is properly bedded, jointed, and covered with mortar and "grout," which is simply the mortar reduced by water to a proper consistency. It is poured over the work, and penetrates into the body of the masonry, thus filling all cavities and assisting to keep the work moist during its progress, thereby producing an even settlement. It may be well to mention that this work is not done by contract, in which case the author considers so free a use of "grout" would not be advisable, as probably it would be made to perform imperfectly what ought to be done thoroughly with mortar. When using bricks they are in all cases moistened, as, if set dry or warm, the mortar would be robbed by absorption of the necessary moisture for its proper hardening. From practice it is found that a cubic yard of rubble work contains one-third and brickwork one-fourth of a cubic yard of mortar. The paper was concluded by a few remarks on the selentic patent process of mixing mortar, the practical manager of the company being present to explain the method, which, owing to his absence this evening, the author has thought it well to omit.

Since writing the foregoing paper the author has had opportunities for extending his researches, and with the permission of this meeting he will briefly mention one or two points. In "The Engineer" of December 3d, 1869, a very lucid description is given of the construction and working of Hoffman's annular kilns, the scientific arrangement and practical attainment of which it would be well to study previous to setting

up kilns for any purpose whatever. During a visit to the continent the author was invited to inspect one of these kilns near Boulogne, employed to burn bricks, and was supplied by the proprietor of the brick-field with the following particulars: The burning of 15,000 bricks requires three tons of coal, costing 90 francs, and the labor of two men one day, 10 francs, in all 100 francs, or £4, being equivalent to 5s. per thousand, which he considered was about half the ordinary cost. Whether the exact saving will reach this amount or not is a question to be decided by those familiar with the working details of brick manufacture; but the economy of the system is, in the author's opinion, beyond question; for when visiting some large lime-works in the neighborhood of Dorking, where two of these kilns were employed, the opinions of the continental brickmaker were fully endorsed by the manager. The lime here burnt was that commonly known as Dorking. It is slightly hydraulic, and is obtained by calcining the lower or grey chalks. It sometimes goes by the name of grey stone in London, where, being cheap, it is much in demand for ordinary building purposes, costing in the lump only 13s., and when ground 15s. per yard.

Although the first cost of these kilns is very great, still the before-mentioned results and opinions, together with the fact that the contractors for the Metropolitan and District Railways deemed it economical to set up kilns on this principle solely to burn brick for the construction of those railways, and removed them after their completion, will, in the author's opinion, fully sanction the large outlay where there is any amount of work to be got through.

The fall of the Northfleet chimney, and the many letters written to the editor of "The Engineer," on the question, are no doubt fresh im the memories of the members present; but it may be well to reproduce a portion of a letter written by one who states that he has had "some bitter experience in the erection of a shaft:" "If the precaution was taken in building these high chimneys to have a fire placed at the bottom of the cavity or in the shaft every night after the bricklayers had done their day's work, setting each night the work done the previous day, we should run less risks, and save the repetition of such dreadful calamities as the fall of the chimney at Northfleet."

The author, being of opinion that this advice was most misleading, and would, if carried out, be the cause of augmenting "such dreadful calamities," thought it well to reply, and although the text of his letter is embodied in this paper, he will quote a few lines, as the statements may be of value, having remained uncontradicted by the criticising public:

"The sun or heat will not set mortar; it simply dries it, and by so doing robs it of the n cessary amount of moisture required for its proper hardening, and thus materially reduces its resistance to crushing, as well as adhesive and cohesive strength. Mortar set in summer is not generally so good as that set in winter—of course, leaving frost out of the question. The expedient of placing a fire in the shaft of a chimney with the object of 'setting each night the work done the previous day' should never be resorted to. Mortar should never be hardened by heat; it would be equally justifiable to use warm bricks, which, it is needless to state, is contrary to sound engineering practice and the theory of mortar.—Nov., 1873."

We are told that this chimney was in design considerably more stable than many similar ones now standing; that it was constructed on a solid bed of chalk, with the best bricks, in the most approved manner; that the work was not pushed, and that there was not the slightest "scamping," all of which statements there is little reason to doubt; and to make things doubly sure, the mortar used in some of the work was composed of Dorking lime, sand, and Portland cement, which, in the author's opinion, had something to do with its failure, for lime and cement are very different in their action; the former hardens slowly, almost solely by the absorption of carbonic acid; the latter immediately (comparatively) by forming a crystalline double silicate of lime and alumina without the absorption of carbonic acid. The lime would certainly not attain any great hardness at the end of eight or ten days. If ground lime was used it would slake and expand some time after the cement had begun to set; consequently the mass would be disintegrated and little better than sand, unless the proportion of cement was very small, in which case the particles of set cement would be separated, and form a matrix round which the lime mortar could form a film as with sand; whether the lime was ground or

previously reduced to powder by slaking, it is questionable if the cement might not give an excess of alumina to the compound, and thus render it liable to contraction and the work to uneven settlement. Unfortunately, sufficient data are not at the author's disposal to enable him to give opinions with confidence, but those stated are to some extent borne out by the author's experiments, and by the fact that on the destruction of the chimney with gun-cotton, a portion, 5 feet in height, was blown away and every brick parted.

"Ah! you cannot make mortar or construct works as the Romans used to do," is an exclamation with which those engaged in construction are more or less familiar. Nevertheless, it is an erroneous conclusion, founded by the comparison of their work with the flimsy structures put up by speculative builders in the cheapest and worst possible manner. But when their works are compared with such as those of Mr. John Fowler, whose Metropolitan brickwork cost more to pull down than it did to erect, and their mortar with such as that employed by the engineer to the Mersey Harbor Board, their doings sink into insignificance; for this mortar, when six months old, sustains nearly the same tensile strain as the highest result of tests with Roman mortar taken from the South of France and recorded by Vicat, the average result of experiments with these two mortars being nearly two to one in favor of the former. And the author has been called upon to test and report on lime mortar which has at the age of six months sustained a tensile strain twice greater than that of the highest result above referred to, which was taken from the Tour Magna and had centuries of time to its advantage. Too much care cannot be exercised in ascertaining the proper proportions of lime, sand, and other ingredients. It is a peculiar circumstance that the better and more hydraulic a lime the less sand it will take up when made into mortar. Blue lias, among the most hydraulic and strongest natural limes to be found in England, like our artificial and natural cements, is completely spoiled by an excess of sand. To prove this, bricks were bedded in the manner previously described, with blue lias and common grey stone lime mortars, mixed in the proportion of one lime to four of sand, and at the age of three months required respectively 140 lbs. and 336 lbs. to tear them asunder. Had the proportions of lime to sand been one to two the results would in all probability been more than reversed. Blue lias is obtained in Somerset, Dorset, Glamorgan and Warwickshire. The following is an analysis, made by Professor Daniells, of blue lias found in the last mentioned county: Carbonate of lime, 87.2 per cent.; carbonate of magnesia, 1.4 per cent.; silica, 5.5 per cent.; oxide of iron, 0.5 per cent.; alumina 2.0 per cent.; bitumen and water, 3.4 per cent.; total, 100.0 per cent. The cost of this lime, delivered in London in December, 1873, was 25s. per ton when ground, in which state it is usually used, being somewhat troublesome to slake when in the lump, and unless the mortar is mixed in a mill, or thoroughly slaked, it is difficult to handle, as it will begin to set in ten or fifteen minutes—not a desirable property unless in the case of hydraulic construction, where it is invaluable; the mill keeping the mixture in motion, will do away with these very quick-setting properties without in the least damaging its ultimate strength or hydraulic qualities. The brickwork of the Metropolitan Railway was made with mortar composed of this lime, ground in a mill for from fifteen to twenty minutes; and it is only fair to the proprietors of the lime-works to say that in the destruction of the work only a short time after its erection, the bricks as often broke through themselves as through the mortar-joints.

In no material of construction is the ignorance of the "practical man" more manifest than in his treatment of mortar. He will often argue that since it is advisable to "sour" lime for the purpose of the interior decoration of houses, that therefore it should be so treated for all other work, forgetting, or not knowing, that by this means its indurating properties are much, if not quite impaired; but had he the sense to know and admit his ignorance, he would only prove himself to be little behind the most experienced and learned men on the subject, for sound conclusions cannot be formed without analyzing the properties of the lime, sand and other materials of which the mortar is composed. The study of the question in this manner yielding no immediate returns, is quite beneath the "practical" man's consideration.

Whether lime is to be used for mortar or concrete, it should, in the author's opinion, have time to slake before being put in place,

and if ground lias or other eminently hydraulic lime, a good practice is to spread it under a shed the night before it is intended for use, and so slake it by the moisture of the night air.

It must always be borne in mind that the strength of a chain is in its weakest link; so also the strength of brickwork subjected to tensile strains is in its mortar. In conclusion, the author would advocate a thorough study of details, as it is only by their mastery that one can hope to attain eminence or position in any profession or trade.

THE PHILOSOPHY OF WELDING.

By W. MATTIEU WILLIAMS, F. R. A. S., F. C. S.

From "Iron."

In the address of M. Jordan, President of the "Société des Ingenieurs" delivered at the annual meeting of the society in Paris, and reporter in IRON, pp. 650 and 679, a novel explanation of the welding of iron is offered. M. Jordan says that welding "is a phenomenon exactly similar" to the regelation of water, the phenomena of regelation being these, that if two or more pieces of ice at a temperature not lower than their melting point, or preferably at a temperature much higher than their melting point, be pressed together, the liquid water adhering to their melting surface becomes solid at the places of contact, and thus the two pieces are refrozen into one. M. Jordan very aptly illustrates the phenomena of regelation by the making of a snowball, telling us that this may be done "when snow is at a temperature not lower than 0. deg. centigrade, *i.e.*, the freezing point of water. Every man who has been a boy will confirm this, and remember that when the snow was very dry, and the temperature of the air below the freezing point, the snow-flakes would not cohere without the aid of much pressure and warmth from the hand, but that with sloppy snow during a thaw, he could make a hard icy snowball with ease. M. Jordan compares the making of the snowball by the children with the welding of the iron-ball by the puddler, maintains that the processes are identical, and applies Sir W. Thompson's rather recondite explanation of regelation to the cases of iron and platinum welding.

It appears to me that this explanation is fallacious, as the conditions of solidification in the two cases are not only by no means alike, but are diametrically opposite, the welding of both iron and platinum being effected at a temperature considerably below their melting point, while the primary condition for the cohesion of two pieces of ice by regelation is that they shall be exposed to a temperature above, or at least, not below, their melting point. In order that regelation should be analogous to welding, it should take place at a temperature far below the freezing point. Now it is well known that under such circumstances regelation does not and cannot occur, and therefore it differs essentially and primarily from welding.

If it had been discovered that two or more pieces of iron, while in a furnace, raised above their melting point and streaming into fusion, would cohere when pressed together, and that this cohesion resulted from the solidification of their liquid surfaces, in spite of the melting heat of the furnace, we should then have an analogy with the regelation of melting ice, and M. Jordan's conclusions would be justified. Regelation means the resolidifying of a liquid, or a special cohesion in spite of liquidity, welding means a special cohesion in spite of solidity, or apparent solidity. If M. Jordan had described them as examples of curiously opposite actions the comparison would have been more nearly correct. We might plausibly assume that, while the pressing together of two pieces of wet ice produces a solidification of the surface liquid, the pressing together of two pieces of heated iron has the opposite effect of momentarily liquefying the surfaces of contact, and thereby soldering them together. The plausibility of this explanation is increased by the fact that pressure develops heat, and thus the welding heat might, at the surface of contact, be momentarily raised to the fusing point, and then, on the removal of the pressure this liquid film might solidify and thus produce the welding cohesion. But even this theory is, in my opinion, too

learned. A far simpler explanation may be found, and we must never forget that when two or more explanations equally fit a given set of facts, the simplest is the best, and usually the true one.

In order to find a true analogy to welding we need go no further than the vulgar "sticking together" of two pieces of cobbler's wax, pitch, putty, or clay. These are in a viscous or semi-fluid condition, and they cohere by an action similar to the transfusion or intermingling and uniting of two liquids. Iron and platinum pass through a viscous or pasty stage on their way from the solid to the liquid states, and the temperature at which this pasty condition occurs is the welding heat. Other metals are not weldable, because they pass too suddenly from the solid to the liquid condition. Ice, although it fuses so slowly, in consequence of the great amount of heat rendered latent in the act of fusion, passes at once from the state of a brittle crystalline solid to that of a perfect liquid. It passes through no intermediate pasty stage, and therefore is not weldable, or does not cohere like iron, etc., at a temperature below its fusing point.

It is usual to cite only iron and platinum, or iron, platinum and gold as weldable substances, but this, I think, is not correct. Lead should be included as a weldable metal. The two halves of a newly-cut leaden bullet may be made to reunite by pressure, even when quite cold. This is obviously due to the softness or viscosity of this metal.

Outside of the metals there is a multitude of weldable substances. I may take glass as a typical example of these. Its weldability depends upon the viscosity it assumes at a bright red heat, and the glass maker largely uses this property. When he attaches the handle to a claret jug, or joins the stem of a wine-glass to its cup, he performs a true welding process.

The chief practical difficulty in welding iron arises from the fact that at the welding heat it is liable to oxidation, and the oxide of iron is not viscous like the metallic iron. To remedy this oxidation the workman uses sand, which combines with the oxide and forms a fusible silicate. If he is a good workman he does not depend upon the solidification of this film of silicate, as the adhesion thus obtained would be merely a soldering with brittle glass, and such work would readily separate when subject to vibratory violence. He therefore beats or squeezes the surfaces together with sufficient force to drive out from between them all the liquid silicate, and thus he secures a true annealing or actual union of pure metallic surfaces.

Cast iron or steel containing more than two per cent. of carbon cannot be welded. Why? I think I may venture to reply to this oft-repeated question by stating that the compound of iron with so much carbon is much more fusible than pure iron, or than steel with less carbon, and that it runs more suddenly or directly from the solid state into that of a liquid, and hence presents no workable range of weldable viscosity.

HYDRAULIC VALVES.*

From "Engineering."

ON VALVES SUITABLE FOR WORKING HYDRAULIC MACHINERY.

Since hydraulic power is now so extensively made use of in iron and steel works for a variety of purposes, any improvements in the machinery necessary to apply this power must be welcome to many members of this Institute, particularly if these improvements tend not only to facilitate the working, but also to reduce wear and tear and consequent frequent repairs, renewals and stoppages.

Making the joints of pipes and other stationary parts present few difficulties, the packings of the glands for rams and piston rods and the packings for pistons require more attention, because, if these are bad they will cause a greater amount of friction than is necessary to secure tightness, or they will be the constant source of leakage. The self-tightening leather collars and leather cups are up to the present time the only reliable packing for water under high pressure, but for pressures up to, say, 500 lbs. per square inch several other kinds of packing seem to answer well; but the parts to which this paper is

* Paper read before the Iron and Steel Institute at Barrow. By Mr. Robert Luthy.

particularly intended to draw your attention are the distributing valves or cocks required to work the different hydraulic apparatus. Some of these valves have to be of considerable size in order to give the proper speed to the machinery; for the tipping cylinders of Bessemer converters their ports are usually made proportionate to pipes of 2 inch bore, and for the centre-ladle-cranes they are even larger. The valves for the tipping cylinders have four ways, and those for cranes and hoists usually only three. As the water from the pumps is generally stored up in an accumulator, it is necessary that all the valves be so constructed that there can be no direct communication between the pressure and the exhaust sides in any position of the valves, *i. e.*, they must have sufficient "lap" to prevent loss of water. The valve faces have to be held together with sufficient pressure to keep the valves tight, and this causes considerable friction.

In earlier arrangements of Bessemer plant, taper brass cocks were almost exclusively used. The plugs of the cocks for the tipping cylinders having a medium diameter of 3 inches, were worked by a handwheel 24 inches in diameter, with intermediate gearing proportioned 1 to 4, thus making a total leverage of 1 to 32. To keep these cocks moderately tight, even when newly ground in, the plugs have to be screwed down so much that it takes a considerable pressure of both hands applied to the wheel to turn them. It is impossible to keep taper cocks tight for any length of time, owing to the difference in the space through which the top and bottom parts of the plug have to travel.

Valves have also been introduced in which the ports are disposed in a circle on a flat surface, and having a disc with recesses in the under side working radially upon the stationary face to bring the pressure and waste ports alternately into communication with the front or back end of the hydraulic cylinder. These valves are open to the same objection as all others having an oscillating or a revolving motion, with surfaces exposed to wear by friction at different distances from the centre of motion.

Brass slide valves of the usual D pattern, similar to steam engine slide valves, do very well for smaller sizes, and if their working surfaces are made of hard metal they last a considerable time; but for larger sizes the friction becomes so great, that in order to work them by hand, a very great leverage has to be employed, and this prevents the valves being opened or closed quickly enough.

Mitred plug valves are used in some places; they are opened or closed either by a screw cut on the spindle itself and working in a nut, or they are held on their faces by weighted levers which have to be raised for opening; separate valves have to be used for inlet and outlet, which makes the arrangement complicated and expensive, and it requires a great deal of room.

All the valves above described have metallic surfaces, and as the stationary face is generally in one piece with the body of the valve and with the connecting branches, considerable stoppages are caused in grinding or otherwise trueing up the surfaces from time to time, and when the faces are worn away, the principal body of the valve or cock has to be replaced at a considerable expense.

Valves have been introduced in which the peculiar properties of the leather collars for making hydraulic joints have been applied to the best advantage. The body of the valve is bored and cored out so as to form chambers communicating with the inlet and outlet pipes and with the pipes for the crane or press cylinder. The ram or slide is turned to fit the smaller bore of the valve, and has recesses turned in it to form annular passages for the water, and carries leather collars, the outer lips of which work against the bored part of the valve. Inside the valve there are also stationary leather collars, whose inner lips make the joint against the larger portions of the ram. The leathers and recesses of the valve and of the ram are so divided that in one position of the latter its larger portions are within the stationary leathers, and its movable leathers within the smaller portions of the valve, thus preventing any communication between any two adjoining chambers; in a second position of the ram or slide, its reduced portions come opposite the stationary leathers, and thus leave an annular passage for the water from the inlet chamber to the chamber in communication with the cylinder; in a third position, the communication between the inlet chamber and the cylinder is again closed, and the leather on the ram is drawn within the chamber communicating with the cylinder, and thus allows the water from the latter to pass into the outlet or waste chamber.

In valves for double-acting cylinders, the leathers and recesses are so arranged that one end of the cylinder is in communication with the pressure and the other end with the waste at the same time. The pressure on the ram in these valves is balanced in every direction, and in moving it, only the friction of the leathers has to be overcome. As some of the leathers work against the body of the valve, it is necessary that this, as well as the ram, are made of brass to obviate corrosion, which would materially increase the friction and cause the leathers, as well as the valve itself, to be quickly worn out. The ram has also to be made in parts screwed together, in order to secure the moving leathers.

With the view of making the body of the valve of iron, removing all the friction from the same and limiting it to the ram, making all the leathers stationary and of uniform size, and the ram in one piece and of such construction that it limits its stroke, and that, after removing the top gland bolt nuts, the gland and all the leathers can be withdrawn at one operation with the ram and quickly replaced, the author of this paper has designed the valve represented by the two illustrations exhibited. One of these is a full-size drawing of a double-acting valve, suitable for working the tipping cylinder of a Bessemer converter, and adapted to take the place of the original four-way cock on the distributing box at present in use in most Bessemer works. On each side of the slide valve a mitre stop valve is introduced, so that the water can be shut off from the pressure and waste pipes, when the leathers in the valve or in the tipping cylinder have to be changed, or any repairs done in the connections between the main range and one vessel, without interfering with the working of the other vessels or the rest of the hydraulic machinery connected with the same main ranges of pipes. This provision has great advantages, and should be made for each separate apparatus.

The valve box is made of cast iron, and has branches for inlet, outlet, and for the pipes leading to the front and back end of the tipping cylinder. It is bored out uniformly down to the shoulder on which the brass ring supporting the leathers and the distance ferrules for the same, rest, and is fitted at each end with a gland through which the ram passes. The brass distance rings fit easily in the box, are bored to fit the ram, and turned on their ends to fit the concave and convex parts of the leathers as required. Their central portions are cored out larger to give sufficient passage for the water to pass all round the ram, and they have portholes to their sides to correspond with the branch openings in the box. The whole of the leathers and rings are firmly held in their places by the top gland, which is screwed down upon the common packing at the top. The ram, which is cast of hard bronze, is divided into a number of cylindrical pieces, connected by feathers or ribs of a cross section, forming passages for the water. The working portion of the ram is turned to an uniform diameter to fit inside the rings, and the ribs at the lower portion project a little, and form stops to limit the stroke of the ram by butting against the lower brass ring and the bottom of the lowest chamber when the ram is moved up or down. These projections serve also for withdrawing the whole of the rings and leathers with the ram when the gland bolt nuts are removed. The edges of the cylindrical portions are rounded off so that they may enter the leathers easily. When the ram is in its central position, the solid portions are within every leather collar, and the valve is thus divided into five compartments. The water under pressure is in the central or inlet chamber, and cannot pass into the chambers on each side of it which are in connection with the front and back-end of the tipping cylinder respectively, as the lips of the leather collars are turned towards the centre and make perfect joints with the ram as well as with the sides of the box The top and bottom chambers are connected by a passage at the side of the box with the outlet branch. When the ram is moved down into the position shown on the drawing, the water is admitted to the back of the cylinder through the openings formed between the ribs of the ram and the interior of the leather, at the same time a similar communication is established between the two upper chambers, letting the water from the front of the cylinder into the waste-pipe. When the ram is moved into its highest position, the pressure will be admitted to the front of the cylinder, and the back will be open to the waste pipe. As the cylindrical part of the ram enters the top and bottom leathers from the inner or open side, the lip is protected from being cut off by being held

back and secured in a groove, turned out of the brass ring, so that only about one-eighth part of an inch of the depth of the leather is free to make the joint with the ram. For the two inner leathers, this is not necessary, as the ram enters them from the back or round side; their lips are protected, however, from being bent in too much by the passing water, by lips in the central ring. A few small holes are drilled through the sides of the brass rings to admit the water to the inside of the leathers. To insure the brass rings being put into the box with their ports exactly opposite the corresponding ports in the box, a shallow groove is slotted down one side of the interior of the latter, and corresponding pieces to fit this groove are brazed to the outside of the brass rings. To prevent corrosion of the inside of the box it is coated with a thin layer of copper, deposited by galvanic process. With a single cranked lever of one to twelve, a lad can work the valve with great ease. Where there is very little pressure in the waste-pipes, it is not necessary to carry the ram through the bottom of the valve, as shown on the drawing, a slight back pressure not being able to move the ram upwards, by overcoming the friction of the leathers and the weight of the ram.

The second drawing shows a smaller and single-acting valve, fitted to an ingot crane. The water enters the top chamber; the central chamber is in connection with the crane, and the lower chamber with the waste-pipe. Part of the ram is here shown simply turned smaller for the passage of the water to the cylinder; the lower passage in the ram, however, is again shown with ribs of a cruciform section and the projection stops.

It will be observed that there is a leather cup instead of a collar at the bottom of this valve as for ingot cranes or reversing gear cylinders, where the load has never to stand in a fixed position for any length of time, a good fit of the brass rings on the ram is sufficient to make that joint.

Many of these valves have already been applied to converters, centre-ladle cranes, lifts, reversing gear for rail mills, and presses for the manufacture of tuyeres for converters, and they all give great satisfaction. The leathers last a very long time, and if a valve has to be examined, or fresh leathers put in, it can be done in a few minutes.

HEAT AND ITS RELATION TO CONSTRUCTION.

From "The Building News."

Heat plays an important part in the economy of construction, and yet its effects are generally unheeded. Light and sound are readily discoverable by our eyes and ears, and therefore have received some attention on the part of architects and others interested in public assembly rooms and halls. On the contrary, heat is a condition not so palpably perceived; and gradations of heat are still less evident, therefore we are dependent, to a great extent, on the aids which thermometry affords. We are not concerned here in discussing the theories of heat, whether it be considered as a subtile form of matter, or caloric, as the "emission" theorists maintained, or whether it be simply the undulation of an imponderable elastic ether pervading space, and which physicists have now called the "Dynamical theory," or a "mode of motion." The able investigations of Drs. Tyndall and Joule, and others have shown "heat" and "power" to be convertible terms. The effects of friction, percussion, chemical action, all tend to establish the vibratory nature of heat, and to place it upon as secure a footing as the undulatory theory of light.

We propose here to indicate some of the common effects of heat in construction, and to show the disarrangements that may take place by great changes of temperature upon materials of different kinds, densities, and degrees of conductivity. As buildings are seldom composed of homogeneous substances of equable rates of expansion or contraction, it becomes a matter of some interest to consider what antagonistic forces are called into exercise by the combination of iron, stones, timber, &c., which are usually rigidly connected with each other, and how far these forces may, in course of time, or during a fire, impair the efficiency of construction, or the stability of the structure.

The expansion of metals is one of the most

serious questions connected with structures, and is often instrumental in dislocating bearing parts of a building, and weakening the entire fabric. We have latterly recorded in these pages several instances in which iron employed in girders and columns, both cast and wrought, has aided rather than averted the destructive action of fire and heat. In large warehouses in which iron girders form a complete network or frame within the brick or stone shell, the effect of any combustible material taking fire is to immediately cause such an expansion and pushing out of the walls that this disturbance alone becomes more thoroughly destructive than the ultimate power of the flames. The alternate action on such a build ng is first to push asunder the walls, and thereby di-locate all bearings, and then the same girdering or framework, becoming red hot, bends itself under the weight of floors or roofs, and either draws together again the walls, or what is most commonly the case, leaves its bearings and falls bodily inwards, to the total destruction of all internal parts. It is this double action which takes place in a fire that places iron in the unenviable position of a destructive agent, rather than as a resisting one. It is somewhat surprising that architects and engineers so frequently neglect this expansibility of metal in girders, ribs, columns, &c., and provide no means for their free movement. Sometimes, it is true, the bearings of long girders in bridges are made of sufficient depth to allow for this increase of length; but even in these cases the mere weight of iron and superincumbent loads upon the points of support render the intended result nugatory, the weight of the iron girder alone often creating so much friction on the bearing surfaces as to overcome the rigidity of the supporting piers or walls, or the cohesion of mortar at certain points. This immovability of the ends of iron girders and joists is often increased by their being clenched or fixed by the weight of wall above, which often improperly is allowed to bear upon the top flanges.

To obviate this, engineers have contrived movable bearings more or less effective. One simple method we would suggest. Let each template be of cast iron of sufficient substance and bearing surface, and let it be placed upon an under template of stone or metal, the surfaces being either left smooth simply or brought into contact by a friction roller of small diameter, and of the length of the bearing surface. By this means free dilatation could take place, provided, of course, the ends of girders are left a free space of sufficient distance. No weight should be allowed to rest upon the ends of these beams, but in all cases the bearings should be free all round, and may be made as cast-iron sockets, built into the wall, or standing out independently.

The linear expansion a bar of iron undergoes when heated from the freezing to the boiling point, or from 32 deg. to 212 deg. Fahrenheit, is about one 812th of its length; at higher temperatures the elongation becomes more rapid. Thus the progressive dilatation of wrought iron, as determined by Daniell's pyrometer, allowing one million parts at 62 deg. is as follows:

At 212°.	At 662°.	At fusing point.
1,000,984	1,004,483	1,018,378

Cast iron is rather less.

It may be mentioned here that the expansions of volume and surface are calculated by taking the linear expansion as the unit, following a geometrical law, thus the superficial expansion is twice the linear; and the cubic expansion three times the linear.

These figures show how sensible a change takes place when iron undergoes an ordinary variation of temperature; and it may be said that in all ordinary cases of building this change is quite sufficient to cause serious disruptions of parts. Thus a bar or beam of even 10 feet long and subject to an ordinary change of temperature, say from 32 deg. to 180 deg, will elongate more than $\frac{1}{8}$th of an inch—a sufficient modicum to cause fracture to stonework, to snap the thread of a screw, or to endanger a bridge floor or roof truss. When we think of lengths ten and even a hundred times this dimension, the danger of uncompensated expansion or contraction is increased a thousand-fold. In ordinary cases the margin of safety is really dependent upon the amount of flexibility or elasticity of the parts of a building connected with iron, or to imperfection of joints; yet we should not rest satisfied with such presumptive security.

It would appear that the most promising mode of using iron is in combining it with

concrete, brickwork, and other materials; but it appears to us such a combination would be still be more advantageous if the iron were completely imbedded or encased in such materials. Thus the "Dennett Arch" offers an example of a compact mass of concrete and iron, the girders being surrounded by the concrete spandrels of arching; there are also other systems of fire-proof construction (*e. g.* Hornblower's) in which the rolled iron joists are completely imbedded and ceiled underneath, and which seem to insure the desired requisites, and which do not expose any considerable surface of metal underneath.

It becomes a serious question, then, how far may iron be used in the construction of floors and roofs without its endangering the actually stability of a building? Or to what extent can iron be used in conjunction with other meterials?

Now, these questions turn upon the possibility of rendering iron less liable to the direct action of fire or heat. Metals are, we all know, the best conductors of heat. Physicists tell us the reason, viz., because their internal structure is homogeneous and uniform; the particles are in close contact; and the vibratory or molecular movement which sets the heat waves in motion is, therefore, regular. All substances which cannot transmit molecular motion readily are bad conductors. Now, it is evident that, if we can combine these two opposite qualities in such a way as will neutralize or destroy the direct action of heat, and, at the same time, without unduly increasing the bulk of our floors and metallic framework, the great problem of how best to utilize iron in construction will be solved. It appears that there are some substances particularly bad conductors of heat; such are brick-earth, composed of a variety of bodies and porous; porcelain, asbestos, pumice-stone, charcoal, sand, &c. These substances are, in fact, such bad conductors that a red-hot iron ball may be held some time in the hand if it be first coated with one of them. Such materials offer themselves as coverings for iron girders, columns, &c., and we do not see why compound materials of a porous kind, as animal charcoal and plaster, should not be applied to such ironwork *in situ* by first filleting the girder or column, or surrounding it with a perforated plating of thin earthenware or metal on which to lay the coating, which could be run as moulded work or finished ornamentally. A lining or casing of such materials moulded to the form of the iron to be protected could also easily be prepared in cast blocks, rebated or grooved together, the external facing being moulded to any section. We do not know of any such preparation, but we throw out the suggestion to manufacturers.

Animal charcoal should be one of the ingredients in the compound used, as it is one of the worst known conductors. Fireclay lumps could be well treated in this manner, or plastering—which materials have been suggested lately. Some success has attended the experimental testing of girders and columns cased in plaster and cement, the particulars of which appeared in the "Building News" some time since. A week or two since, the fireproof construction adopted at the National Safe Deposit Company's premises underwent a severe trial at the works of Messrs. Easton & Anderson, Erith, an experimental beam, cased in fireclay lumps, and coated with plastering, being subjected to the action of a continuous flame for one and a half hours, and to a smoldering heat for twenty-four hours. The floor thus subjected formed the top of the furnace, and was composed of two brick arches supported upon an iron girder cased as above, and was loaded to an equivalent distributed load of 3 cwt. to the super. foot. A deflection of 3-16 inch in centre took place. In about an hour after exposure to the fire, the plaster coating cracked, and came off in pieces; and the deflection increased for some hours after the fire was reduced till it reached 1 inch and 3-16 th, after which it diminished, and when the fire was extinguished by a stream of water and the load removed a deflection of 3-8 inch remained. The deflection, however, gradually diminished, and the girder eventually regained its straightness. The fireclay reached a red-heat, but was found afterwards precisely as when put on, "quite uninjured," though some part of the brick side of furnace was forced by the heat out of the perpendicular, possibly by the thrust of the arches.

This experiment has successfully proved that iron protected with fireclay can withstand a fierce heat and yet remain uninjured in its elasticity, while the brick arching and concrete backing can resist any amount of heat likely to occur. We think if an air-space were left between such casing and the iron, it would provide a still

more effectual barrier, though a few perforations would be required in the casing to allow the heated and expanded air to escape. If, also, brick-earth mixed with charcoal were used, a still more effectual non-conducting casing would be obtained, and the iron would be comparatively preserved at a moderate temperature. By thus encasing a good conductor of heat in a bad one, the evils of expansion and contraction are avoided, or considerably lessened, and we are thus left the advantage of using in our construction a material which may aptly be called a "good servant but a bad master."

Not only would non-conductive coverings act as protectors from heat, but they would obviate the inconveniences arising from condensation. Space prevents our consideration of this and other effects of heat, which we may leave to another article; in in the mean time, however, we hope to find the promoters of the Amended Metroplitan Buildings Bill will consider the importance of casing iron likely to be exposed to fire, and the desirability of preserving powers to enforce the employment of fire-resisting and non-conducting materials; to regulate thickness of walls in warehouses, their horizontal and vertical division, and also to insist upon means of compensating for the expansion of iron under heat, and generally to exercise control in the arrangement of inflammable buildings.

PRACTICAL IRONWORK.

From "Engineering."

In offering the following remarks on practical ironwork to the consideration of a meeting of members of one or more grades of this great Institution, of which the author is proud to be a student, no time will be wasted by prefatory detail; but as all present are more or less familiar with the subject, it will simply be assumed that the skeleton of an iron structure has been decided upon, and the strains ascertained to which each of its members are to be subjected, and the purpose of this paper will be to investigate the practical considerations affecting its design, strength and construction.

No attempt will therefore be made to delineate the process by which these strains have been arrived at, as that portion of the subject can only be mastered by deep and patient study of existing structures and standard works on the subject.

In apportioning the proper amount of metal to meet the strain, the first care should be to employ as nearly as possible only iron of the economical sections, weights and lengths to be obtained in the iron market; points not unfrequently overlooked. For instance, L-irons 4 in. by 4 in. by ½ in. can be obtained in lengths of 30 ft. without extra cost, and they are sometimes rolled at an additional cost to 40 ft. in length. At the Vienna Exhibition a Z-section of rolled iron was exhibited 85 ft. in length. L's and T's, and similar sections can be obtained in moderate lengths without extra charge, when the sum of the sides does not exceed 8 in. or 9 in.; with larger sections, such as H-iron, having a depth of about 12 in., the cost will be something over 20 per cent. more than for T or L irons, complying with the above conditions. In the same way an extra price is generally paid for bars exceeding 6 in., although up to 8 in. or 9 in. it is not excessive, and they can be obtained from some manufacturers up to 12 in. in width.

It is in dealing with plates that the term "extra" must always be kept in view, as by bad designing the cost of the iron may be nearly doubled. A plate to cost the ordinary market price must be under 4 cwt. in weight, 15 ft. in length, 4 ft. in width, and must not be of irregular shape. In order to better illustrate this point, a plate 15 ft. by 5 ft., 1 in. by ⅜ in. may be taken as an example, and the extra charges, according to formal tender made in 1873, by a first-class firm for "Best crown boiler plates," will be:

	£	s.	
For weight	12	0	per ton.
" length	0	0	"
" width	3	10	"
" cutting	0	0	"
In all	15	10	

The price for iron by this tender complying with the previously mentioned conditions was £19. 10*s.*, to which this extra charge must be added, bringing it up to £35

per ton, or nearly double the cost of ordinary plates.

These considerations must be attended to in designing buckled, corrugated or other manufactured forms of plates, as, if they require to be made from iron on which "extras" are charged, their cost will necessarily be enhanced.

At the Vienna Exhibition plates were exhibited 52 ft. 6 in. by 5 ft. 3 in. by 63 in. and 48 ft. 7 in. by 4 ft. 2 in. by 1.23 in., weighing 3 and 4½ tons respectively; these were of course exceptional and very costly plates.

The "extras" for plates do not become very considerable until a weight of 7 cwt. is exceeded, and a width of 4 ft. 6 in.; but when the width of 5 ft. is reached, the extra is charged per inch, and by the tender before referred to it amounts to 10*s.* per inch per ton, in addition to £3 charged extra for a width of 5 ft.

A long plate becomes expensive on account of the difficulty in handling it, and the great care required to be exercised in putting it through the rolls, in order to avoid making it of irregular shape, in which case there is a large amount of waste in cutting the plate to the required length and area, and sometimes it becomes what is technically termed a "waster," which has to be thrown aside; to cover these contingencies, much larger "blooms" have to be made.

Contractors have sometimes to tender for ironwork when the designs contain many of these irregular lengths and dimensions; it then becomes necessary for them to estimate the probability of the conditions of the design being enforced, not always an easy matter; but when the reason for the employment of extra iron is obvious, they tender accordingly. Occasionally designs exhibiting a total ignorance of ironwork come into the contractor's hands, in which case estimating becomes very difficult, and to be on the safe side, a large percentage must be put on to cover contingencies.

The contractor can generally estimate the quality of the work which will suffice by the workmanlike style or otherwise in which the drawings and specifications are made out.

Angle-iron bends and joggles should be as few and simple as possible, and bent or cut plates should be few and far between.

T-stiffeners to the web of a plate-girder, if splayed out clear of the angle-iron, will cost about half as much for smithing as when required to fit close round them, and will answer their purpose equally well; where the flanges are too narrow to admit of four rows of rivets being put through at one cross-section, this form of stiffener cannot be used; where the flange requires only two rows of rivets, but is of sufficient width to admit of two additional rivets, the stiffeners can be generally so arranged that these rivets shall in no way affect the strength of the girder, as owing to the unvarying thickness of plates there is always an excess of strength in the flanges of a plate-girder at points not very far distant, and it is here that the stiffeners should be placed.

The harassing little, but still most important rivets, should be carefully considered, as it is on them that the whole strength of the structure depends—no amount of extra metal in the body of a tie can compensate for a badly constructed joint. The author would advise careful consideration of the position, diameter, and pitch of every rivet previous to placing the design before contractors, as carelessness or ignorance on this point at once indicates the amateur designer, who is often led astray by the facility with which he can ornament his drawings with these little circles or red crosses.

Drawings of ironwork should be as complete as it is possible to make them, free from all ambiguity, leaving no room for doubt as to what is intended; in order to effect which dotted lines must largely be employed. It is impossible to confuse a drawing by putting dotted lines in their proper places, as it must be borne in mind that the drawings are not to be submitted to a parliamentary committee, but to men accustomed to most complicated mechanical drawings. A working drawing is not necessarily pretty; it should be neatly and accurately made, and should require no explanation whatever.

The pitch and diameter of the rivets should in all cases be marked upon the drawings, and their relative positions in the structure should be pointed out. In the construction of a bridge, it is generally necessary to draw the whole or parts of it full sized, with its required curve or camber, in order to ascertain the accurate length of its separate portions and the exact relative positions of the rivets, which will, by this means, be very accurately ascertained; these positions will then be marked on a

template, from which any number of similar plates can be made.

It is usual to specify that when one portion of a structure is to be riveted to another, the holes must be made with such accuracy that a template with studs fixed in the relative position of the rivets one-sixteenth less than them in diameter, shall enter all the holes at the same time and go completely through the various thicknesses of plates; if the holes are not fair to one another, the shearing area of the rivet is reduced, and therefore the joint will not be of its calculated strength, to cover which fault it is advisable in calculating the number of rivets to consider their diameter one-sixteenth less than that shown on the drawings; all rivets should have a good and sufficient head, and when inspecting the construction of ironwork this point should be enforced.

The strength of rivet iron will be considered hereafter, but a good practical test is that a rivet shall be hammered, when hot, to less than $\frac{1}{8}$ inch in thickness without showing any sign of cracking.

Although a difference of opinion exists among engineers on the question of drilled *versus* punched holes, it would appear from the following experiments carried out by Mr. Cochrane and kept on record in the Minutes, vol. xxx., that practically there is little to be gained, so far as the strength of the plates is concerned, by using one method more than the other.

A bar of Lowmoor 2 inch $\times \frac{1}{2}$ inch with a drilled hole $\frac{7}{8}$ inch in diameter put through it, sustained 235 cwt., and with a punched hole 226 cwt.; with bars of hard crystalline iron of the same dimensions, that with the drilled hole sustained 250 cwt. and the punched hole 244 cwt. With bars each with three holes, one drilled, one punched, and one punched $\frac{3}{4}$ inch and drilled to $\frac{7}{8}$ inch in diameter, in all cases they broke through the punched hole, which would be inferred from the above results, but which are still well within the limits of variation of the breaking weights of our best irons.

When we leave strength out of the question and consider only workmanship, the method to be adopted must be left to the judgment of the engineer. If a number of plates are to be riveted together or an intricate junction made, unless great care is exercised by a very experienced hand at a punching machine, the drilled holes will be more accurate, but where a simple plate and L-iron are to be joined together the balance of strength in favor of drilling is not sufficient, in the author's opinion, to sanction the extra cost.

A want of proper welding in the lamina of iron may be sometimes detected when punching; it is difficult to punch near the edge of bad iron, but a drill may be put through almost any rubbish.

The cost of cast iron may be greatly enhanced by bad designing, but as civil engineers have not often to deal with very intricate forms it may be sufficient to say that the molten metal is run into moulds, and that, with the exception of very large castings which are built up bodily, these moulds are formed by placing in the sand a pattern in wood of the object to be cast. Of course this is well known to all, but still not always remembered, if we may judge from the number of boxes and cores sometimes required for what ought to be simple castings.

In a casting such as a transverse truss of an arch bridge, the different portions of the truss should have nearly the same amount of cross section, as if this is not attended to the members with the smaller body of metal will cool first, and the remaining portions in cooling will put an initial strain on the iron which may distort or even cause its destruction; for these reasons every precaution should be taken to insure that the casting may cool evenly.

As regards the quality of cast iron, for want of space a few words must suffice. For structural purposes it should be melted at least twice, and mixtures should be made which will stand the following test: A bar 3 feet, 6 inches by 2 inches by 1 inch, run each day from the cupola from which the castings are being made, should, when placed edgeways on 3 feet bearings, sustain a load applied at the centre of 28 to 30 cwt., and give before breaking a deflection of five-sixteenths.

The cast iron of the sleepers for the Great Indian Peninsula Railway had to undergo tests very similar to this, and, in addition, the sleepers had to stand a weight of $3\frac{3}{4}$ cwt. falling a height of 5 feet 6 inches, the same having previously been subjected to blows from this weight falling 2 feet, 2 feet 6 inches, 3 feet, etc., up to 5 feet, 6 inches, being at the time of testing on sand not more than 24 inches deep; the average height required to break the sleepers was

7 feet, 9 inches. The cast iron was also to stand a tensile strain of 11½ tons per square inch, and the average was 13.07 tons, a very high but obtainable result.

It is not advisable to restrict the manufacturer by stating the proportions and classes of iron to be mixed, as he will in most cases be better able to judge of the mixtures to be made in order to produce a specified result. Not that the author would advocate leaving too much to the practical man, as we not unfrequently come across the "miscalled practical man," who will tell you that he is able to judge of iron by its appearance, a statement which must be accepted with caution, as men who have given much more time than most engineers can devote to the study of iron, very often err in their conclusions formed only by inspection. An instance came under the author's notice where a fracture of rod iron was shown and pronounced first-class, and on the other end of this rod, not 6 inches in length, being exhibited it was pronounced little better than trash; in the first instance, the fracture was of a fine silky, fibrous nature, which denotes that the iron is soft, tenacious, and generally of good quality, while in the latter case it presented a rather coarse crystalline fracture. which, owing to the largeness of the crystals, showed that the iron was not quite of a uniform quality, but the appearance was chiefly owing to the mode of testing, as if iron is broken by a sudden strain it invariably presents the crystalline fracture; whereas if good iron, and broken by a gradually increasing strain, the fibrous fracture always results; nevertheless, it is the generally accepted opinion that the fibrous fracture cannot be obtained by any mode of testing from really bad iron; the gradually increasing strain should therefore be applied, and the fibrous fracture must result from good iron, more especially from rolled iron or plates.

Whether the iron is fibrous or crystalline, its quality may to some extent be judged by the fineness of its texture, and the irregularity of its fracture.

Ironmasters are to some extent averse to testing; the author was advised by one of these gentlemen of high standing to exhibit his knowledge of the subject by simply specifying "best merchantable iron," and if, after inspection, it was found not to be good, it could then be tested, but after what has been said it is needless to further point out the impropriety of such a proceeding; it was also hinted that tests were instituted to exhibit the cleverness of engineers, instead of which they simply exposed ignorance, and no doubt there is often room for such remarks.

According to Mr. Edwin Clarke, the permanent set of a bar 10 feet long and 1 square inch in section was for 3 tons, strain $\frac{1}{468.750}$ and at 10 tons $\frac{1}{74\ 953}$ of its length. The stretch of iron up to 12 tons is to some extent uniform, and may be taken at $\frac{1}{10.000}$ of its length for each ton, but beyond this strain it becomes irregular, which accounts for the ultimate deflection of a beam being almost beyond calculation.

In the early days of engineering it was a common practice to make things strong enough, on the erroneous supposition that a structure tested with something more than its working load would be quite safe. This may or may not be true according to whether the limit of elasticity of the iron is exceeded. If such be the case the ultimate destruction of the structure is only a question of time; under any circumstances the design of a structure on such an hypothesis is now quite inadmissible owing to the increased cost of labor and materials, and the criticism to which a design is always subjected.

The limit of elasticity of iron is that point at which the same strain will produce an increasing permanent set. An example will perhaps more clearly express this important point. If a bar be tested with a load of 8 tons and the permanent set not increased by any number of repeated applications of this load, 8 tons is said to be within the limit of elasticity of the iron; if on the other hand the permanent set increases ever so little, the limit of elasticity has been exceeded.

It would, therefore, be well to specify that iron shall not take an increasing set with 8 or 9 tons, but that with 11 or 12 tons it must show a decided permanent set over and above that obtained with the 8 tons. The latter condition is required in order to insure the first being complied with, as an unprincipled manufacturer might put a higher strain than 8 or 9 tons, and so take all the stretch out of the iron previous to its official testing, in which case any iron would comply with this condition. This point is, in the author's opin-

ion, one of great importance, for supposing the working strain put upon the iron to be 5 tons to the inch, although this may in some cases be only $\frac{1}{5}$th of the ultimate breaking strain, the factor of safety will only be 1.6 in place of 5 as might appear at first sight, that is assuming the limit of elasticity to be 8 tons.

The working strain to which iron is to be subjected is governed by the specified quality and tests to which it is to comply with. In moderately small structures, where the working load is comparatively great in comparison with the weight of the structure, it will be found in most cases more economical to employ an ordinary quality of iron with a small working strain, than to use an exceptionally good material; the working strain of the iron is also governed by the character of the load. In the case of a girder supporting the wall of a building a strain of 5½ tons might with safety be put upon good ordinary iron, but in a small railway bridge of about 20 feet span, where the moving load is to a great extent indeterminable, it is not well to impose a greater strain that 4 or 4½ tons.

From the author's experience and a careful study of the many results obtained by such high authorities as Mr. Kirkaldy, he concludes that ordinary iron to be found in the market should comply with the following conditions:

Rod, bar, and rivet iron should sustain an ultimate tensile strain of 24 tons per square inch, elongate 15 per cent. before breaking, and be reduced in sectional area about 25 per cent. Angle iron, an ultimate tensile strain of 22 tons, elongate 9 per cent., and be reduced in sectional area about 15 per cent. Plates with the fibre an ultimate tensile strain of 20 tons, elongate 6 per cent. and be reduced in sectional area about 8 per cent., and across the fibre 18 tons, elongate 3 per cent., and be reduced in sectional area about 5 per cent.

—	Tons per square inch.	Elongation per cent.	Contraction of area per cent.
Rod, bar and rivet iron	24	15	25
Angle iron	22	9	15
Plates with fibre .	20	6	8
Plates across fibre ..	18	3	5

These requirements are not at all excessive, and should therefore not enhance the price of ordinary Staffordshire beyond the insignificant sums for testing purposes. The samples on which these investigations are to be carried out ought to be from 8 inches to 10 inches in length, between the points of attachment. The toughness and ductility of the iron can be estimated, either from the contraction of area or elongation; it is unnecessary, therefore, to investigate both of these points, the choice between them being decided by the facility with which they can be ascertained, but where the experiments are to be carried out at testing works, such as those of Mr. Kirkaldy, it is immaterial which is specified, as by experience either may be ascertained with equal precision.

No doubt the carrying out of tests will involve the expense of continuous inspection, but the engineer by vigorously enforcing his specification, will not only gain the esteem of every honest contractor, but will have the satisfaction of knowing that he is obtaining good materials and workmanship.

On the completion of the structure it should be tested with a load slightly greater than its working load, and the deflection noted. This test of workmanship must only be taken in conjunction with the test of materials, as a joint or portion of the structure might be on the point of breaking and yet not stretch sufficiently to materially alter the deflection, and hard brittle iron under the deflection test may appear superior to a better and more desirable quality.

If an iron structure is well designed, erected, and taken care of, the author can see no reason why the term "life of ironwork" should not become a thing of the past, as iron imbedded in concrete has been found at the expiration of twenty years as free from decay as on the day of its manufacture.

A few words on the preservation of ironwork will, therefore, perhaps not be out of place. It is advisable to coat a casting with oil, paint, or tar, as soon as it leaves the sand, as by so doing the hard outer skin is preserved, and when in position it should be again coated. When cast iron is to be covered up, a preparation of coal tar and naphtha is found to answer well; this may also be used to advantage for the upper surface of buckled plates or other forms of road platforms.

Wrought iron when hot from the rolls is sometimes brushed over or dipped into boiled linseed oil, but a better and less expensive way, in the author's opinion, would be to brush it over with boiling hot oil when cut to something like its permanent shape, and after its workshop manipulation to again treat it with oil; previous to being erected any abutting surfaces should be also coated with red lead or other metallic paint. A preferable way, if thoroughly carried out, would be to let the iron slightly rust and have it well scraped before its treatment with oil, as by so doing the oxide or blue shales, which in a more or less degree are inseparable from its manufacture, would be removed; they are very apt to peel off after a short time and bring the paint with them, more especially in a structure subject to vibration. This is not of such vital importance for home work under constant supervision, but for foreign up-country-work too much care cannot be taken to preserve the surface of the iron from atmospheric and other influences.

All work should be so designed to allow of its being painted, and plates less than $\frac{1}{4}$ inch in thickness should never be used. The linseed oil brushed over the iron, as before pointed out, will form a kind of varnish, and is an excellent preparation for the after coats of red lead or other metallic paint, of which not less than two coats should be used, the last being of approved color and put on after the work is erected in place. On account of the great cost of red lead, other metallic paints are now generally substituted, as that expensive ingredient was often replaced by colored earths, which were mixed with bad oils, and it is needless to state that the quality of the paint is, to a great extent, governed by the oils with which it is made.

All tooled surfaces should be well covered with tallow and white lead. Those wishing to become acquainted with the practical items of ironwork cannot do better than study "Works in Iron," by Mathieson, and experiments on wrought iron and steel, by Kirkaldy; but a year devoted to the vice and bench in a good ironwork or general mechanical shop will be of more service than any amount of reading, and we have it on no less authority than Mr. John Fowler, that a mechanical training is absolutely essential to those aspiring to any eminence as civil engineers.

In conclusion the author trusts his *confrères* exonerate him from any desire or attempt to exceed his province as a student, by the terms which he has found it necessary to employ in his treatment of "practical ironwork."

ELASTICITY OF BUILDING MATERIALS.

From "The Building News."

When two balls of ivory, hard wood, or metal impinge against each other with a force very much less than that which would suffice to break them, a rebound takes place one from the other, which is caused by a slight flattening having been produced at the point of contact; and the force of this recoil depends upon the power possessed by the material of resuming its former shape; this power is the measure of the "elasticity" of the body, or its tendency to resist any displacement of its fibres. No material is perfectly elastic; the fibres or particles of the body strained never exactly recovering their original position; hence a large succession of blows will gradually alter the shape of the body, provided they are not sufficiently strong to produce fracture. There are, however, many degrees of elasticity in various materials, which can be discovered by carefully conducted experiments; thus, if two balls of the material to be tested are suspended by threads, so as to move in an arc of a circle, and allowed to fall towards each other from a certain height, they will not return to the point from which they started, but to some point short of it, the arc traversed in the recoil, as compared with that traversed in the descent, giving the measure of the "elasticity" of the material, or the ratio of the force of restitution to that of compression. In this way the relative elasticity of several bodies has been ascertained; taking 100 to represent perfect elasticity, or the distance on the arc or scale from which the bodies start towards each other, it is found that glass has the greatest power of restitution, its elasticity being as high as 94; that of hard

baked clay is 89; of ivory, 81; of limestone, 79; of hardened steel, 79; of cast iron, 73; of soft steel and bell-metal 67; of elm wood, 60; of brass, 41; and of lead, 20. This mode, however, of testing the elasticity of bodies tells us very little about the actual elastic force residing in the material; for although glass has a much higher elasticity than steel, yet a blow that would not make the slightest impression on the latter would smash the former to atoms. For practical purposes we have, therefore, to ascertain by a different class of experiments what force a body will withstand without injury to its elasticity or power of retaining the shape that has been given to it.

When a straight bar or rod of any hard material is fixed at one end, and a pressure applied to the other, a bending in the direction of the pressure will be produced, the amount of which depends on the relative proportions of the bar, and the amount of force applied. In some materials, such as brick or stone, the bending will hardly be perceptible, as the application of a weight that would produce any appreciable amount of flexure would fracture the material; with iron, steel, wood, and many other substances, the case is very different, the amount of bending being very considerable before injury or fracture takes place; when, however, the pressure is removed the bar never returns exactly to its original straightness, but retains a "set" or alteration of form, owing to the imperfection of its elasticity. Thus in an experiment that was tried on a small cast-iron bar whose section was the form of ⊥, which was supported at each end and loaded in the middle, and of which the breaking weight was found to be 1,120 lbs., the deflection in the centre, or deviation from a straight line, caused by a load of 14 lbs., was 1-40th of an inch, and the set after the removal of the load was just perceptible; with a load of 56 lbs. the deflection was 4-30th of an inch, and the set 1-200th of an inch; but with 112 lbs. the set was three times as great as with 56 lbs. Hence it appears that however small the strain the elasticity is to some extent weakened thereby, and, consequently, the resisting power of the material. Fortunately, however, the set does not go on increasing in any perceptible degree as long as the beam is loaded with a weight very much less than that which would cause fracture, this ratio varying in different materials from 1-3rd to 1-10th of the breaking load.

Another mode of testing the elasticity of a material is to subject it to a stretching force in the direction of its length; if the material was perfectly elastic it would, after being elongated by the force applied, return to its original length as soon as the strain was taken off; that it never does so is evident from the following experiments:—A rod of cast iron 50 feet long and 1 inch square being subjected to a stretching force was found to require 16,000 lbs. to tear it asunder; but before this was done it was gradually strained by a succession of weights, and when the strain amounted to 1-10th of the breaking weight it stretched 11-150ths of an inch, and the permanent set when the load was removed was 1-500th of an inch; with double this load the rod stretched just twice as much, but the set was 1-100th of an inch, or five times as much as before; with half the breaking weight the extension was nearly ½ an inch, and the set 1-20th of an inch, the ultimate extension at the moment of fracture being 1 inch. Hence we see that cast iron, when subjected to tensile strain, possesses a high degree of elasticity as long as the stretching force applied is only a small proportion of the breaking force, since the "set" is but 1-30th of the actual extension produced by 1-8th of the breaking weight, and amounts to 1-15th of the extension when the strain is ¼ of the breaking weight. We may therefore consider that for all practical purposes cast iron is perfectly elastic under a tensile strain as long as it does not exceed 1-8th of that which would tear it assunder; also that within this limit the elongation is proportional to the strain; hence if L is the original length, l the extension produced by a force S, E a constant number called the "modulus of elasticity," then

$$l : L : : S : E$$

If we make l equal to L, then S will be equal to E; and hence it appears that E is the force necessary to elongate a rod one square inch of section by a quantity equal to its original length. The value of E has been determined for many solid bodies by experiment, and is employed in all calculations of the resistance of bodies to change of form. If S is the force that will produce an elongation l in a rod 1 inch square, then $S \times A$ is the force which will produce the same extension, in one of A inches in sec-

tion; or putting $S \times A = F$, we have

$$S = \frac{F}{A};$$

and since $E : S :: L : l$.

Therefore

$$E : \frac{F}{A} :: L : l, \text{ and } l = \frac{F.L}{E.A},$$

or,

$$F = \frac{E.A.l}{L}.$$

The value of l gives us the elongation produced by a given force F, and the value of F in the last equation gives the force required to produce a given elongation l. Putting

$$S = E\frac{l}{L},$$

we have $F = S \times A$. The "modulus of elasticity E is the constant relation existing between the tension per unit of area, and the corresponding proportional elongation which it produces. From the foregoing experiment we can, therefore, deduce the numerical value of E, since

$$E = S\frac{L}{l};$$

and when S = 4,480 lbs.,

$$\frac{L}{l} = \frac{50 \times 12}{\frac{1}{8}}, \quad \therefore E = 13{,}440{,}000 \text{ lbs.},$$

for cast iron.

When a bar is subjected to a compressive force in the direction of its length, it is shortened thereby in proportion to the force applied; but when the pressure is removed its elasticity enables it to return to its original length, or very nearly so, provided the amount of pressure has not approached near to that which would crush the material. An experiment of this kind was made on a bar of cast iron, 10 feet long and 1 inch square, inclosed in an iron frame to prevent bending, the compressing force being applied at one end. Under a pressure of 4,200 lbs. the bar yielded 1-23rd of an inch, and when the load was removed the "set" was scarcely perceptible, being only 1-14th of this decrement. Under 6,300 lbs. the compression was 1-15th of an inch, the set bearing the same proportion thereto as before. With a load of 8,400 lbs. the bar yielded 1-12th of an inch, but the set was 1-10th of the compression; also with 10,500 lbs. the set was in like proportion to the compression, which was a little over 1-10th inch. With an increase of the force the set increased more rapidly in proportion to the compression, being more than 1-8th of it when the load was 21,000 lbs. Taking the compression under a force of 8,400, we find the modulus of elasticity from the equation

$$E = S\frac{L}{l},$$

namely, E = 11,454,545 lbs. for cast iron under compression.

When bars of wrought iron are subjected to tensile strains, they will stretch much more than those of cast iron before breaking, and the set is very small until the strain reaches one-half that which will tear the fibres asunder. A bar 1 inch square, and 10 feet long stretched 1-22nd of an inch under a strain of 10,670 lbs., which was 1-5th of the breaking load, and on its removal it recovered its original length almost exactly, the "set" hardly amounting to 1-100th of the extension produced; with double the strain the extension was twice as great, but the set nearly four times as much as before; with half the breaking load the extension was nearly 1-8th of an inch, and the set 1-100th inch, or 24 times as great as with a strain of 1-5th the breaking load. In this case the elasticity was but slightly impaired under a strain equal to half that which would destroy the material, since the extension was in proportion to the force applied. Hence we find the value of E for this material to be 27,834,783 lbs. for tensile strain, by taking the value of l, when S=10,670 lbs.

The elasticity of wrought iron under a compressive force has been determined by experiments similar to those employed for cast iron, by inclosing a rod 10 feet long and 1 inch square, in an iron frame, to prevent it from bending. Under a pressure of 10,000 lbs., the decrement of length was 1-20 inch; with 20,000 lbs., it was 2-20 inch; and with 30,000 lbs. it was 3-20 inch; showing that the law of compression being proportional to the load held good to that extent, and that the elasticity of the material was hitherto unimpaired; in this case the "set" increased nearly as the square of the compression of each renewal and removal of the load. Beyond 30,000 lbs. on the square inch, the compression increased with greater rapidity the elasticity being evidently impaired thereby, so that we may consider this as the utmost compressive strain to which wrought iron can be safely subjected. Taking the compression under a weight of 20,000 lbs., we find,

in the same way as before, E=24,000,000 lbs. for wrought iron under compression.

The value of the modulus of elasticity (E) is required when we want to calculate the deflection which a beam will undergo when supported at the ends and loaded in the middle; in which case the amount of deviation from a straight line is found by multiplying the weight into the cube of the length, and dividing by the moment of inertia of the section of the beam taken about its neutral axis, and by 48 times the modulus of elasticity. Hence the value of E can be calculated by observing the deflection produced by a given load. Thus, the moment of inertia of a rolled iron joist of I section is $12\ (b.\ D^3 - \overline{b - t}.\ d^3)$, where b is the breadth of the flanges, D the total depth, d and t the depth and thickness of the web; the deflexion of this beam was .016 inch for every 2,240 lbs. laid on the centre, the span being 54 inches; therefore

$$E = \frac{W \times l^3}{48 \times .016} \times \frac{1}{12\ (b.D^3 - \overline{b - t}\ d^3)} =$$

22,467,200 lbs., the depth D being 5 in., d $2\frac{1}{2}$ in., b $2\frac{1}{8}$ in., and t $\frac{7}{8}$ in.

By means of the modulus of elasticity we can therefore find how much deflection to expect when a beam is subjected to a given load, and can regulate the dimension thereof so that its deflection shall not exceed a fixed amount. When the load is uniformly distributed over the entire length of the beam, the deflection at the centre is $\frac{5}{8}$ths of that produced by the same load all applied at the centre.

The elasticity of steel is much more perfect than that of iron, and consequently it can be loaded with a greater proportion of its breaking weight without injury. A bar of hardened steel 1 inch square being laid on two supports 54 inches apart, a load was applied at the centre beginning with 50 lbs., and increasing gradually by that amount until it reached 1,400 lbs. Under 800 lbs. the deflection was 1 inch; with 1,000 lbs. it was $1\frac{1}{4}$ inch, and with 1,200 lbs. a little over $1\frac{1}{2}$ inch, showing the increase of deflection to be nearly as the strain. With a load of 1,200 lbs. a slight "set" was observed, amounting to .016 inch, which was quadrupled by the addition of another 50 lbs.; from this point the deflection and set increased more rapidly, being 1 4-5ths of an inch and .133 inches respectively, under a strain of 1,300 lbs., and with 1,350 the set was .429 inches; hence it appears that the elasticity remained perfect until the load exceeded 1,200 lbs.

A bar of steel being subjected to a tensile strain, showed no indication of a set until the strain was one-half that which would tear it asunder, so that this material may be strained to that extent without injury to its elasticity. The same may be said of steel when it is subjected to a crushing or compressive force. The modulus of elasticity of the best steel is 31,000,000 lbs., but very much less for the inferior qualities.

Wood is a material whose elasticity is easily impaired, for if once it is bent it retains the curvature given to it, so that the strain to which it is subjected must fall very far short of that which would cause fracture. The moment of inertia of a rectangle about an axis through its centre being

$$\frac{1}{12} b\, d^3,$$

where b is the breadth and d the depth, the value of E is obtained from the deflection (δ) of a rectangular beam loaded in the middle and supported at each end, from the equation

$$E = \frac{W}{4\,\delta} \times \frac{l^3}{b\ d^3}.$$

The deflection of an oak beam 2 in. square and 84 in. long, was 1.28 in. with a load of 200 lbs., hence

$$E = \frac{200}{4 \times 1.28} \times \frac{84^3}{2 \times 2^3} = 1{,}447{,}031 \text{ lbs.}$$

From this formula we can find the breadth to be given to a beam of known depth and span in order that the deflection under a certain weight shall not exceed a fixed amount; for

$$b = \frac{W.\ l^3}{4\,E.\ \delta.\ d^3}.$$

The modulus of elasticity for fir can be found by a similar experiment; the deflection of a fir batten 3 in. deep and $1\frac{1}{2}$ in. thick, with a span of 72 in., amounted to $\frac{1}{4}$ in. under a load of 120 lbs.; hence

$$E = \frac{W}{4\,\delta} \times \frac{l^3}{b\,d^3} = 1{,}105{,}900 \text{ lbs. for fir.}$$

Another similar batten gave a deflection of $\frac{1}{2}$ inch under the same load with a span of 8 feet; consequently we have E=1,310,720 lbs. in this case; and another with 10 feet span deflected 1 inch with the same

load, giving E=1,232,213 lbs., which is about the average of the three numbers.

The importance of a knowledge of the elasticity of materials can scarcely be overestimated, since the bending or "sagging" of a beam supporting the wall of a house or other heavy permanent load will cause settlements in all parts of the building, even if it does not actually endanger the stability of the structure.

THE ECONOMIC DEPTH OF TRUSSES.

By S. H. SHREVE, C. E.

Written for Van Nostrand's Magazine.

Among the many interesting problems which present themselves during the investigation of the subject of strains in trusses, that of the economical distribution of material has received but little attention; certain proportions have been taken and certain precedents followed without much thought being given to the matter. It is true, that as yet, owing to some unsettled points, theory will enter to some extent into discussions of economy of material, but our assumptions are very closely allied to facts, and the results which may be obtained have great practical value. In many special cases the proportions for stiffening, for joints, for horizontal bracing, and for other parts which have been assumed at a certain percentage, may be definitely fixed, and enable us to obtain results which are accurate.

Certainly that which tends to solve the problem:—given the span and the weight to be carried to determine the most economic form or depth of truss—must, at least, be interesting to the practical engineer.

It is the latter question, that of the economic depth of truss, that we propose investigating in the present paper.

Disregarding its own weight, the quantity of material in a member of a truss varies directly as its length and the amount of strain to which it is subject. Thus a wrought-iron rod or bar subject to tension must have, for a safe working load, a section of 1 sq. in. for each 11,000 lbs. of strain to which it is subject; or if S represent the load or strain which the rod is supporting, its correct section will be $\frac{S}{11000}$; and since a bar 1 in. square and 1 ft. long weighs 3.368 lbs., $\frac{3.368\ S}{11000}$ is the weight of 1 ft. of the bar or rod, and multiplying by r, the length of the rod, we have

$$\frac{r\,S}{3266} = Q, \quad . \quad . \quad . \quad (1),$$

the weight of a rod whose length is r, which will safely support the load or strain S.

The same process of reasoning applies to a strut or column subject to compression, only since 9,000 lbs. may be taken as the safe compressive load for wrought iron, Eq. (1) may be changed to

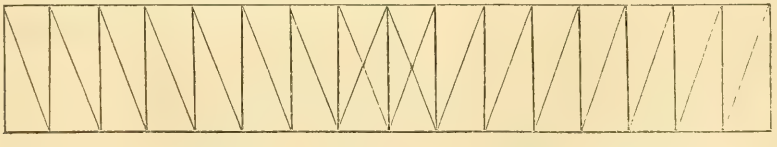
$$\frac{r\,S}{2672} = Q, \quad . \quad . \quad . \quad (2).$$

No allowance is here made for the extra quantity of material required for joint connections, and it is not necessary at this point in the case we are considering, to allow any, since our results do not affect the number of joints; but in the struts a certain allowance must be made for stiffening and rivet holes. For this one-third will be ample, and we consequently leave Eq. (1) as it is, and make Eq. (2) one-third greater or in even numbers.

$$\frac{r\,S}{2004} = Q, \quad . \quad . \quad . \quad (3)$$

is the weight of a strut subject to a strain S.

Let Fig. (1) represent a truss with a



simple system of bracing consisting of vertical struts and inclined ties, then the Eq.

$$= \frac{(w' + w)\,x}{2\,d} - \frac{(w' + w)\,x^2}{2\,dl}, \quad (4),$$

will give the strains in the chord members when the truss is fully loaded.

Here w' = the weight of the uniformly distributed movable load,
w = the weight of the truss,
l = the length of the truss,
d = the depth of the truss,
x = the distances of the ends of the chord members from the abutment and is measured in the upper chord to the ends nearest the centre and in the lower chord to the ends nearest the abutment and is confined to values not exceeding $\frac{l}{2}$.

Let p= the length of the chord members; hence we can obtain the weight of any upper chord member by substituting Eq. (4) for S of Eq. (3) and multiplying by p instead of r; or the weight of any upper chord member is

$$\left(\frac{(w'+w)x}{2d} - \frac{(w'+w)x^2}{2dl}\right)\frac{p}{2004} = Q. \qquad (5)$$

The successive values of x in this equation are p, $2p$, $3p$, etc., to $\frac{np}{2}$, n being the number of panels in the truss; so that by substituting these values in the equation and summing the series thereby formed, we evidently obtain the weight of one-half of the upper chord.

Taking the first term of Eq. (5) we find that it increases in arithmetical progression, thus:

$$\frac{w'+w}{2d}\left(p + 2p + 3p \ldots . \frac{np}{2}\right),$$

and the sum of this series is

$$\left(\frac{w'+w}{2d}\right)p\left(\frac{n^2+2n}{8}\right). \qquad (6)$$

The second term becomes

$$\frac{w'+w}{2dl}\left(p^2 + 4p^2 + 9p^2 \ldots . \frac{n^2p^2}{4}\right)$$
$$= \frac{w'+w}{2dl}p^2\left(1 + 4 + 9 + \ldots . \frac{n^2}{4}\right),$$

and the sum of this series is,

$$\frac{w'+w}{2dl}p^2\left(\frac{n^3+3n^2+2n}{24}\right). \qquad (7)$$

Replacing these terms in Eq. (5) and for np putting its value l, we obtain,

$$\left\{\left(\frac{w'+w}{2d}\right)\frac{ln+2l}{8} - \left(\frac{w'+w}{2dl}\right)\times \left(\frac{l^2n+3l^2+2pl}{24}\right)\right\}\frac{p}{2004}$$
$$= \frac{w'+w}{4008d}\left(\frac{l^2}{12} + \frac{pl}{8} - \frac{p^2}{12}\right),$$

and doubling this,

$$= \frac{w'+w}{2004d}\left(\frac{l^2}{12} + \frac{pl}{8} - \frac{p^2}{12}\right) = Q, \quad . \quad . \quad (8)$$

is the quantity of material in the upper chord. For the lower chord from Eqs. (1) and (4) we have similarly,

$$\left(\frac{(w'+w)x}{2d} - \frac{(w'+w)x^2}{2dl}\right)\frac{p}{3266}, \quad . \quad . \quad . \quad (9)$$

but in this case the limit of the values of x is $\frac{np}{2} - p$, as will be seen by reference to the figure. Performing the same process as with the equation for the upper chord, Eq. (9) becomes

$$\frac{w'+w}{3266d}\left(\frac{l^2}{12} - \frac{pl}{8} - \frac{p^2}{12}\right) = Q, \quad . \quad . \quad (10)$$

the quantity of material in whole lower chord. Adding Eqs. (8) and (10), we have

$$\frac{(w'+w)l^2}{14903.4d} + \frac{(w'+w)pl}{4085.6d} - \frac{(w'+w)p^2}{1490.3d} = Q,$$

or, since the last two terms of the equation will not amount to more than a very small percentage of the whole quantity, they may be omitted and we shall have

$$\frac{(w'+w)l^2}{14903.4d} = Q, \quad . \quad . \quad (11)$$

for the quantity of material in the two chords.

The strain upon any strut from the constant load will be given by the following equation:

$$V = \frac{w}{l}\left(x - \frac{p}{2}\right). \quad . \quad . \quad (12)$$

Here x is measured from the centre of the truss to the strut and the load is considered as concentrated at the lower chord panel points.

Substituting Eq. (12) for S in Eq. (3), and for r the length of a strut, d, we have

$$\frac{\frac{w}{l}\left(x - \frac{p}{2}\right)d}{2004} = \frac{wxd}{2004l} - \frac{wpd}{4008l} = Q, \quad . \quad (13)$$

the quantity of material in any strut distant x from the centre of the truss. The different values of x are, as before, p, $2p$, $3p$, etc., to $\frac{np}{2}$, whence, summing the series and putting l for np we obtain for the first term,

$$\frac{wd}{2004}\left(\frac{n}{8} + \frac{1}{4}\right),$$

and for the second term, which is a constant

and applies to every strut, and consequently to be multiplied by $\frac{n}{2}$, we get,

$$\frac{wd}{8016},$$

whence,

$$\frac{wd}{2004}\left(\frac{n}{8}+\frac{1}{4}\right)-\frac{wd}{8016}=\frac{wdn}{16032}=\mathrm{Q}. \quad . \quad (14)$$

the quantity of material in one-half the strut and

$$\frac{wdn}{8016}=\mathrm{Q}. \quad . \quad . \quad (15)$$

the quantity of material in all the struts from the constant load.

But $n=\frac{l}{p}$, whence Eq. (15) becomes

$$\frac{wdl}{8016\,p}=\mathrm{Q}, \quad . \quad . \quad (16)$$

or the quantity of material in the struts required for the constant load varies directly as the depth and as the length of the truss, and inversely as the length of the panels, while the quantity of material in the chords varies inversely as the depth, and may be considered here to be unaffected by the length of the panels.

The strain in any strut is to the strain in the tie attached to its upper end as the length of a strut is to the length of a tie, or since the length of a tie$=\sqrt{(p^2+d^2)}$

$$d:\sqrt{(p^2+d^2)}::\frac{w}{l}\left(x-\frac{p}{2}\right)$$
$$:\frac{w}{dl}\left(x-\frac{p}{2}\right)\sqrt{(p^2+d^2)} \quad . \quad (17)$$

is the strain in any tie, x being the distance from the centre of the truss to the upper end of the tie.

Substituting Eq. (17) for S in Eq. (1), and for r the length of a tie $\sqrt{(p^2+d^2)}$ and performing the same process we have just done with the struts, we obtain for the quantity of material in the ties,

$$\frac{wn}{13064\,d}(p^2+d^2)=\mathrm{Q} \quad . \quad (18)$$

varying with the length of the tie and greater with an increased depth of truss.*

The equation for the strain upon the braces from the moving load is

$$\mathrm{V}=\frac{w'\left(x-\frac{p}{l}\right)^2}{2\,l^2}, \quad . \quad . \quad (19)$$

Where $x-\frac{p}{2}$ is the extent of the load measured from one abutment, and x is the distance from that abutment to the strut whose strain is given by the equation. To apply Eq. (19) we must substitute it for S in Eq. (3) and make $r=d$, the length of a strut. The different values of x are p, $2p$, $3p$, etc., to np. But the greatest strains upon the struts are produced when the truss is half or more than half loaded so that the different values of x are from $\frac{np}{2}$ to np.

Substituting these values in Eq. (19) and summing the series, we have for the amount of strain in the struts of one half the truss, excluding the centre one,

$$\frac{7\,w'n}{48}-\frac{w'p}{48\,l}=\mathrm{S},$$

or for the whole truss,

$$\frac{7\,w'n}{24}-\frac{w'p}{48\,l}=\mathrm{S}. \quad . \quad . \quad . \quad (20)$$

This does not give the strain upon the centre strut, which may be obtained from Eq. (19) by making $x=\frac{l}{2}$, which gives

$$\frac{w'}{8}-\frac{wp}{4\,l}+\frac{wp^2}{8l^2},$$

and adding this to Eq. (20) we have,

$$\frac{7\,w'n}{24}-\frac{7\,w'p}{24\,l}+\frac{w'}{8}+\frac{w'p^2}{8\,l^2}=\mathrm{S}. \quad . \quad . \quad (21)$$

Substituting this in Eq. (3) and for r putting d, we have,

$$\left(\frac{7\,w'n}{24}-\frac{7\,w'p}{24\,l}+\frac{w'}{8}+\frac{w'p^2}{8\,l^2}\right)\frac{d}{2004}=\mathrm{Q} \quad . \quad (22)$$

for the quantity of material required for the struts; and for the ties, as in the previous case of the constant load,

$$\left(\frac{7\,w'n}{24}-\frac{7\,w'p}{24\,l}+\frac{w'}{8}+\frac{w'p^2}{8\,l^2}\right)\frac{p^2+d^2}{3266\,d}=\mathrm{Q}. \quad (23)$$

Collecting the equations we have obtained for the different parts, we have,

$$\frac{(w'+w)l^2}{14903\,4\,d}+\left(\frac{7\,w'l}{24\,p}-\frac{7\,w'p}{24\,l}+\frac{w'}{8}+\frac{w'p}{8\,l^2}+\frac{wl}{4\,p}\right)$$
$$\left(\frac{d}{2004}+\frac{p^2+d^2}{3266\,d}\right)=\mathrm{Q} \quad . \quad . \quad (24)$$

for the total quantity of material in the truss.

If, for convenience, this equation be put in this shape

$$\frac{\mathrm{A}}{d}+\mathrm{B}\left(\frac{d}{a}+\frac{p^2+d^2}{bd}\right)=\mathrm{Q}. \quad . \quad (25)$$

where the values of A, B, a and b are easily

* Stoney, page 182, is of a different opinion. He states, "Hence we conclude that altering the depth of braced girders does not affect the amount of bracing."

seen, and then differentiated with d as a variable, we will obtain for its value, which will make the equation or the quantity of material a minimum,

$$d = \sqrt{\left(\frac{ap^2}{a+b} + \frac{A\,ab}{B\,(a+b)}\right)} \quad . \quad (26)$$

By replacing the quantities of Eq. (24) in this equation and reducing it to its simplest form we obtain for the value of d,

$$d = \sqrt{\left\{ .38\,p^2 + \frac{2\,l^4 p\,(w'+w)}{w'\left\{7\,l^2\,(l-p^2) + 3\,l^2 p + 3\,p^2\right\} + 6\,l^3 w}\right\}} \quad (27)$$

Let w'=200,000 w=100,000, l=200, and p=10, and by substituting these values in the equation we shall obtain for that depth of truss which shall require the smallest quantity of material

$$d = \sqrt{\{38 + 592\}} = 25 \text{ ft.}$$

If we assume the amount of horizontal bracing and the allowance for joints, etc., to be a certain percentage of the weight of the bridge, and we add this, together with the weight of the track to Eq. (24), we shall then obtain the value of w or the weight of the bridge. Thus, let the horizontal bracing and the extra amount of material required for joints and connections be 25 per cent. of the weight of the bridge and the weight of the track, etc.. to be, say 250 lbs. to the foot, then,

$$\frac{(w'+w)\,l^2}{14903.4\,d} + \left(\frac{7\,w'l}{24\,p} - \frac{7\,w'p}{24\,l} + \frac{w'}{8} + \frac{w'p}{8\,l^2} + \frac{wl}{4\,p}\right) \times \left(\frac{d}{2004} + \frac{p^2+d^2}{3266\,d}\right) + .25\,w + 250\,l = w. \quad (28)$$

or,

$$w = \left(\frac{w'l^2}{14903.4\,d} + \left(\frac{7\,w'l}{24\,p} - \frac{7\,w'p}{24\,l} + \frac{w'}{8} + \frac{w'p}{8\,l^2}\right)\left(\frac{d}{2004} + \frac{p^2+d^2}{3266}\right) + 250\,l\right) \div \left(.75 - \frac{l^2}{14903.4\,d} - \frac{l}{4\,p}\left(\frac{d}{2004} + \frac{p^2+d^2}{3266}\right)\right) \quad (29)$$

Let w'=400,000, l=200, d=25, and p=10, and substitute these value in this last equation and we shall obtain for the weight of the bridge, w=268,071 lbs.

RECENT PROGRESS IN MECHANICAL ENGINEERING.*

From "The Telegraphic Journal."

In railroad engineering, one of the most important topics for consideration, as it appears to me, is that which relates to the abatement of dangers in the conducting of the traffic.

Gradually, during a period of twenty or thirty years past, a very fine system of watching, signalling, and otherwise arranging for the safety of trains, has been contrived, and very generally introduced along our principal line of railroad. In saying this, I allude chiefly to the block system of working railways, with the aid of telegraphic signals and interlocking mechanisms for the working of the points and signals.

In former times it was customary to allow a certain number of minutes to elapse after a train passed any station, or junction, or level crossing, or other point where a servant of the company was stationed, before the succeeding train was allowed to pass the same place. Thus at numerous points along the line a time interval was preserved between successive trains. It was quite possible, however, that the foremost of the two trains, after passing any of these places where signals were given, might become disabled, or might otherwise be made to go slowly, and that the following train might overtake it, and come into violent collision with it from behind. In order to provide against the occurrence of such accidents a system was introduced called the *block system;* and its main principle consists in dividing the line into suitable lengths, each of which is called a *block section*, and allowing no engine or train to enter a block section until the previous engine or train has quitted that portion of the line. In this way a space interval of at least the length of a block section is preserved between the two trains at the moment of the later train's passing each place for signalling; and the risk of this space interval becoming dangerously small by negligence or other accidental circumstances, as the later train appoaches the next place for signalling, is almost entirely avoided.

Further, at each signalling station, the va-

*Abstract of the address of Prof. James Thompson, LL D, to the Mechanical Section of the British Association.

rious levers or handles for working the points, and those for working the semaphore signals for guiding the engine-drives, instead of being—as was formerly the case—scattered about in various situations adjacent to the signalling stations, and worked often some by one man and some by another, without sufficient mutual understanding and without due harmony of action, are now usually all brought together into one apartment called the signal-cabin. This, cabin, like a watch-tower, is usually elevated considerably above the ground, and is formed with ample windows or glass sides, so as to afford good views of the railway to the man who works the levers for the semaphores and points, and who transmits by electricity signals to the next cabins on both sides of his own, and, when necessary, to other stations along the line of railway.

The interlocking of the mechanisms for working the points and for working the semaphores, which, by the signals they show control the engine-drivers, consists in having the levers by which the pointsman works these points and signals so connected that the man in charge cannot, or scarcely can, put one into a position that would endanger a train without his having previously the necessary danger-signal or signals standing so as to warn the engine-driver against approaching too near to the place of danger.

The latest important step in the development and application of the block system is one which has just now been made in Scotland, on the Caledonian Railway.. Before explaining its principle, I have first to mention that a semaphore arm raised to the horizontal position is the established danger-signal, or signal for debarring an engine-driver from going past the place where the signal is given. Now the ordinary practice has been, and still is, to keep the semaphore arm down from that level position, and so to leave the line open for trains to pass, except when the line is blocked by a train or other source of danger, on the block section in front of that semaphore, and only to raise the semaphore arm exceptionally as a signal of danger in front. The new change, or improvement, now made on the Caledonian Railway consists mainly in arranging that along a line of railway the semaphore arms are to be regularly and ordinarily kept up in the horizontal position for prohibiting the passage of any train, and that each is only to be put down when an approaching train is—by an electric signal from the cabin behind—announced to the man in charge of that semaphore as having entered on the block section behind, and when, further, that man has—by an electrical signal sent forward to the next cabin in advance—inquired whether the section in advance of his own cabin is clear, and received in return an electrical signal meaning "*The track is clear; you may put down your debarring signal, and let the train pass your cabin.*" The main effect of this is, that along a line of railway the signals are to be regularly and ordinarily standing up in the debarring position against allowing any train to pass; but that just as each train approaches, and usually before it has come in sight, they go down almost as if by magic, and so open the way in front of the train if the line is ascertained to be duly safe in front; and that immediately on the passage of the train they go up again, and, by remaining up, keep the road closed against any engine or train whose approach has not been duly announced in advance, so as to be known at the first and second cabins in front of it, and kept closed unless the entire block section between these two cabins is known to have been left clear by the last preceding engine or train having quitted it, and is sufficiently presumed not to have met with any obstruction, by shunting of carriages or wagons, or by accident, or in any other way. This new arrangement, which appears to be a very important improvement, has already been brought into action with success on several sections of the Caledonian Railway; and it is being extended as rapidly as possible on the lines of the Caledonian Company, where the ordinary mode of working the block system has hitherto been adopted.

The mechanisms and arrangements I have now briefly mentioned are only a portion of the numerous contrivances in use for abatement of danger in railway traffic. It is to be understood that by no mechanisms whatever can perfect immunity from accidents be expected. The mechanisms are liable to break or to go wrong. They must be worked by men, and the men are liable to make mistakes or failures. We shall continue to have accidents; but if we cannot do away with every danger, there is no reason why we should not abate as many dangers as we can.

Within the past twenty years very remarkable progress has been made in steam

navigation generally, and more especially, I would say in oceanic steam navigation. In this we meet with the realization of great practical results from the combination of improved mechanical appliances and of physical processes depending on a more advanced knowledge of thermo-dynamic science.

The progress in oceanic steam navigation is due mainly to the introduction jointly of the screw propeller, the compound engine, steam-jacketing of the cylinders, superheated steam, and the surface-condenser.

The screw propeller, in its original struggle for existence, when it came into competition with its more fully developed rival, the paddle-wheel, meet with favoring circumstances in the want—then strongly felt—of means suitable for giving a small auxiliary steam-power to ships arranged for being chiefly propelled by sails. For the accomplishment of this end the paddle-wheel was ill-suited ; and so the screw propeller got a good beginning for use on long oceanic voyages. Afterwards, in the course of years, there followed a long series of new inventions and improved designs in the adaptation of the steam-engine for working advantageously with the new propeller; and it has resulted that now, instead of the screw being used as an auxiliary to the sails, the sails are more commonly provided as auxiliaries to the screw. For long oceanic voyages it became very important or essential to get better economy in the comsumption of fuel. In order to economize fuel, high-pressure steam, with a high degree of expansion and with condensation, was necessary. This led to the practical adaptation, for the propulsion of vessels, of the compound engine—an old invention, which originated with Hornblower in the latter part of the last century, and was afterwards further developed by Wolff. The high degrees of expansion could not be advantageously used in cylinders heated only by the ordinary supply of steam admitted to them for driving the piston; and more especially when that steam was boiled off directly from water without the introduction of additional heat to it after its evaporation. The knowledge of this, which was derived through important advances made in thermo-dynamic science, led to the introduction into ordinary use in steam navigation of steam-jacketed cylinders, and to the ordinary use also of superheated steam. With increased efforts towards economy of space in the hold of the ship, which became the more essential when very long voyages were to be undertaken, and with the new requirement of greatly increased pressure in the steam, the old marine boilers, with their flues of riveted plates, were superseded by tubular boilers more compact in their dimensions and better adapted for resisting the high pressure of the steam. In connection with these various changes, the old difficulty of the growth of the stony incrustations in the boilers became aggravated rather than in any way diminished. As the only available remedy for this, there ensued the practical development and the very general introduction of the previously known, but scarcely at all used, principle of surface condensation instead of condensation by injection. A supply of distilled water from the condenser is thus maintained for feeding the boilers, and incrustations are avoided. The consumption of coal is often found now to be reduced to about 2 lbs. per indicated horse-power per hour, from having been 4 or 5 lbs. in good engines in times previous to about twenty years ago.

Before the times of ocean telegraph-cables, little had been done in deep-sea sounding; but when the laying of ocean cables came first to be contemplated, and when it came afterwards to be realized, the obtaining of numerous soundings became a matter of essential practical importance. In the ordinary practice of deep-sounding, as carried on both before and since the times of ocean telegraph-cables, until a year or two ago, a hempen rope or cord was used as the sounding-line, and a very heavy sinker—usually weighing from 2 to 4 cwts.—was required to draw down the hempen line with sufficient speed, because the frictional resistance of the water to that large and rough line moving at any suitable speed was very great. The sinker could not be brought up again from great depths, and arrangements were provided by means of a kind of trigger-apparatus, so that when the bottom was reached the sinker was detached from the line, and was left lying lost on the bottom, the line being drawn up without the sinker, but with only a tube of no great weight, adapted for receiving and carring away a specimen of the bottom. For the operation of drawing up the hempen line with this tube attached, steam-

power has been ordinarily used, and practically must be regarded as necessary.

A great improvement has, within the last two or three years, been devised and practically developed by Sir William Thomson. Instead of using a hempen sounding-line, or cord of any kind, he uses a single steel wire of the kind manufactured as pianoforte wire. He has devised a new machine for letting down into the sea the wire with its sinker, and for bringing both the wire and the sinker up again when the bottom has been reached. With this apparatus, in its earliest arrangement, and before it had arrived at its present advanced condition of improvement, he sounded, in June, 1872, in the Bay of Biscay, in a depth of 2700 fathoms, or a little more than 3 miles, and brought up again his sinker of 30 lbs. weight after it had touched the bottom; and brought up, also, an abundant specimen of ooze from the bottom, in a suitably arranged tube attached at the lower end of the sinker.

An important feature in his machine consists in a friction brake arrangement, by which an exactly adjusted resistance can be applied to the drum or pulley which holds the wire coiled round its circumference, and which, on being allowed to revolve, lets the wire run off it down into the sea. The resistance is adjusted so as to be always less than enough to bear up the weight of the lead or iron sinker, together with the weight of the suspending wire and more than enough to bear up the weight of the wire alone. Thus it results that the arrival of the sinker at the bottom is indicated very exactly on board the ship by the sudden cessation of the revolving motion of the drum from which the wire was unrolling. Another novel feature of great importance consists in the introduction of an additional hauling-up drum or pulley, arranged to act as auxiliary to the main drum during the hauling-up process. The auxiliary drum has the wire passed once or twice around its circumference at the time of hauling up, and is turned by men, so as to give the wire extending from it into the sea most of the pull requisite for drawing it up out of the sea, and it passes the wire forward to the main drum, there to be rolled in coils relieved from the severe pull of the wire and sinker hanging in the water. Thus the main drum is saved from being crushed or crumpled by the excessive inward pressure which would result from two or three thousand coils of very tight wire, if that drum unaided were required to do the whole work of hauling up the wire and sinker.

The wire, though exposed to the sea-water, is preserved against rust by being kept constantly, when out of use, either immersed in or moistened with caustic soda. The fact that steel and iron may be preserved from rust by alkali is well known to chemists, and is considered to result from the effect of the alkali in neutralizing the carbonic acid contained in the water, as the carbonic acid appears to be the chief cause of the rusting of steel and iron.

This new method of sounding, depending on the use of pianoforte wire was first publicly explained by Sir Wm. Thomson in the Mechanical Section of the British Association at the Brighton Meeting, two years ago; and in the interval which has since elapsed it has come rapidly into important practical use.

FRENCH PRESERVATION OF TIMBER FROM DECAY.

From "The Building News."

A director of the French dockyards, and inspector of timber for naval purposes, and an officer of the Legion of Honor, ought to have something to say about the preservation of wood which is worth listening to. It appears that it is a fact established by the agricultural statistics of France that the annual consumption of wood in that country considerably exceeds the reproduction, and consequently its preservation for building purposes has now become a question of the very first importance. In short, by the continued impoverishment of the land in that particular, not only are the interests of the agricultural and industrial population immediately affected, but their future requirements compromised and endangered. Very few persons have even an approximate idea of the enormous consumption of timber which takes place annually in France. It is generally believed that the shipbuilders are the principal consumers, and this would be true, to a certain extent, if it only re-

lated to timber of extraordinary or unusual dimensions, but as regards quantity, the consumption for shipping is almost insignificant. M. Burat, Professor of Commercial Statistices in the Institution of Arts and Sciences, does not hesitate to estimate the annual consumption of timber in France in building and manufactures at 353,166,000 cubic feet, to which must be added, 1,059,498,000 cubic feet for firewood, and 529,749,000 cubic feet made into charcoal.

It has long been known that France is in a bad way so far as timber is concerned, and the scarcity of coal, and the consequent use of timber for firewood, completely shuts her out from supplying England with wood, which she might do in course of years. For their own sakes it is to be regretted that the landlords object to having timber round their fields, and to replacing the timber they cut down. No one (who quite understands the timber trade) wants that agricultural lands should be taken from the plough to turn into forest lands, but a judicious cultivation of what may be called "building trees" will always pay, and not impoverish the corn or other cereal power production of the estate. M. De Lapparent, aware of the scarcity, naturally seeks a remedy in making timber more durable by artificial means. Immersion in water is no doubt a beneficial process for timber to undergo, but how long should it remain under water in order to get rid of its sap, or of as much of it as possible? Evelyn says that a fortnight in river water is sufficient. M. De Lapparent recommends one year in river water; two years in fresh water frequently changed; and three years in brackish water, which should always be changing.

At the close of these several periods, the boards intended for planking should be taken out to be in store, or they might be left to season themselves naturally for two years at least before being worked up. As to the rough ribs, seasoning in store would be totally sufficient, and it would require, after shaping but before putting together, to subject it to an artificial seasoning. There have been many plans of this description in use for some time in France and England, but they have only been applied to wood of moderate thickness, such as boards, flooring, and wainscoting. The plan adopted in London is the injection by means of a ventilator of hot air into the drying stove where the wood is placed; by this the temperature is gradually and gently raised until it reaches boiling heat. But as wood is one of the worst known conductors of caloric, if this plan is applied to large logs, the interior fibers will retain their original bulk, while those near the surface have a tendency to shrink, the consequence of which would be cracks and splits of more or less depth.

M. Guibert, of Touraville, near Cherbourg, has taken out a patent which consists of filling the drying stove with smoke produced by the distillation of certain combustible matters, such as sawdust, waste tan, smith's coal, &c. By means of a ventilator ingeniously arranged, a rotatory movement round the logs is given to the smoke, so as to obtain an average uniform temperature in every part. By this plan, as the distillation of combustibles is always attended with a considerable discharge of steam, all cracks and splits appear to be prevented. In this factory, the author referred to has seen a great number of boards prepared by this method, and all perfectly sound.

Messrs. Légé and Fleury Pironnet have invented an apparatus for the injection of sulphate of copper into beech and poplar. If the wood is only required to be seasoned, a warm current of air is substituted for the liquid, and without doubt this process of seasoning would be the quickest, and we should avoid the cracks and splinters always produced when dry and hot air only are applied. The great cost of the apparatus, and its complicated details, are, however, a drawback.

Charring timber is an excellent mode of preservation, and Lapparent has an apparatus for this object by the use of gas. The results obtained from experiments at the gasometer at Cherbourg, with the aid of a meter, and using a jet of average force, were:—1st. Consumption of gas about 200 litres per square meter, at 200 gallons per 10 square feet of carbonized surface. 2nd. Workman's average day's work of 10 hours would carbonize 440 square feet. 3rd. One workman is sufficient for bellows supplying two jets of gas. At full work the expense would not exceed 1½d. per 10 square feet. The operation can be facilitated by smearing, in the first instance, the surface of the timber with a little tar, and with the following advantages:—1st. The carbonization of the cracks is facilitated.

2nd. It prevents the the timber being too suddenly affected by the heat of the gas, which causes it to split. 3rd. It prevents the cracking and splintering off of little ignited particles. Without going to the length of saying that any means of producing indestructible timber are here propounded, still there is something worth remembering in every line. If the results of recent experiments in this country are confirmed, we shall be in a far better position than our French neighbors, and it is to be sincerely hoped that the results will be proved to be established facts, for it will effect a revolution in the building trade, provided the process is inexpensive. In the mean time, and with the recent experience of disasters occasioned by the imflammability of timber and other causes, any contribution which tends to throw any light at all on the means to be pursued towards its preservation is very welcome.

NOTE-BOOK MEMORANDA FOR RAILROAD BRIDGE CALCULATION.

By E. SHERMAN GOULD, C. E.

Written for Van Nostrand's Magazine.

The following is an attempt to establish the calculation of strains in straight trusses, upon a few simple principles, the application of which will, it is believed, solve expeditiously and directly all cases of this very interesting problem.

PRINCIPLES.

1. The action of the panel weights of both truss and load, is concentrated at the apexes of the web members.

2. The strain on the chords is maximum when the truss is entirely covered with the rolling load; the strain on any tie and corresponding strut is maximum when it and the ties between it and the farther abutment only are loaded.

3. The vertical strains, both fixed and rolling, and under all circumstances of loading, both uniform and partial, are transmitted in proportional parts to the abutments.

4. All vertical strains passing through web members toward the same abutment, are of the same character, *i. e.*, all compressive or all tensile, while vertical strains passing through web members to opposite abutments are of opposite characters and exercise upon such members both compression and tension, and the actual strain upon such members is the algebraic sum of the two strains.

5. The proportional part of the weight sustained by any given tie which travels to the nearer abutment exercises a tensile strain upon all ties and a compressive strain upon all struts between it and that abutment, while the proportional part travelling to the farther abutment, exercises a compressive strain upon all ties, and a tensile strain upon all struts between it and the centre of the truss. From the centre to the farther abutment the previous character of strains is resumed, and the ties are strained in tension and the braces in compression.

Note.—When the truss sustains only its own weight, or is uniformly loaded, each tie and strut transmits a strain equal to the whole weight upon it to the nearer abutment. This is because the proportional parts travelling to the farther abutment are compensated by equal and opposite parts on the other side of the centre of the truss.

ELEMENTS REQUIRED.

L = length of truss, in panels.
D = depth of truss, in panels.
W = panel weight of truss.
W' = panel weight of load.
$W'' = W + W'$

$$\text{tang. } \theta . W'' = \frac{W''}{D}$$

$$\text{sec. } \theta = \frac{\sqrt{1 + D^2}}{D}.$$

Note.—θ = angle which sloping members make with the vertical.

PROCESS OF CALCULATION.

1. Make a sketch of one-half of the proposed truss. It had better be drawn accurately to scale.

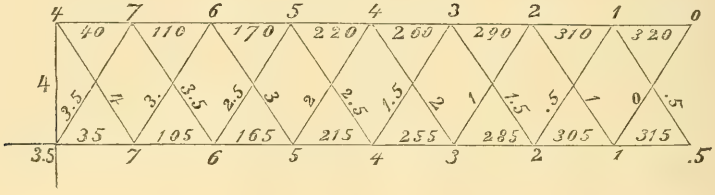
2. Write the coefficient of the panel weight on each tie, directly and transmitted upon such tie and its corresponding strut, commencing at the centre. Add the

coefficients of each pair of sloping members meeting at a common apex, and write the sum at such apex. If only one member is sloping, write its coefficient only at the apex.

3. Obtain the maximum horizontal strain in each panel, beginning at the abutment, by multiplying tan. $\theta \times W''$ by the coefficients of the apexes, and adding the results and writing them on each panel length.

4. Obtain maximum vertical strains by (*a*) tabulating the strains in each tie and strut when under truss weight alone, multiplying for this, W by the co-efficient marked on each tie and strut, and (*b*) by conceiving the whole truss to be covered with the rolling load (LW′) and this weight then removed panel by panel from the abutment to the centre of truss, tabulating successively the strain from rolling load in each tie and its strut as it becomes the last in the loaded segment. This is done by making the number of panels in the loaded segment which the tie under calculation closes, the first term of a decreasing series of which the number of systems in the truss (one, two, etc., according as the truss is a simple, double, etc., truss) is the ratio. The sum of this series, multiplied by W′ and divided by L gives the maximum vertical strain from rolling load, for the given tie. This strain, added to that, already tabulated, of

FIG. 1.



truss load, gives total maximum vertical strain, and being multiplied by sec. θ, gives actual maximum strain in ties and struts.

These strains may be checked by recollecting that the maximum strain on any tie is equal to the strain on that tie when the whole truss is covered with the rolling load, *plus* the strain sent through it to the farther abutment by the rolling weight of the same system between it and the nearer abutment.

APPLICATION.

Let Fig. 1 represent half of a double Warren truss, of the following elements:

L = 16.
D = 1 5.
W = 5 tons.
W′ = 10 tons.
W″ = 15 tons.
tan. $\theta \times W''$ = 10 tons.
sec. θ = 1.2.

Operating as described above, we get the

TABLE 1.

1. No. of Tie and Strut.	2. W	3. W′	4. W + W′	5. W″	6. +	7.	8. × Sec. θ.
1	20	40	60	60	.....	60.	72.
2	17.5	35.	52 5	52.5	.....	52.5	63.
3	15.	30.6	45.6	45	0.6	45.6	54.7
4	12.5	26.25	38 75	37 5	1 25	38.75	46.5
5	10.	22.5	32.5	30.	2 5	32.5	39.
6	7.5	18.75	26.25	22.5	3.75	26 25	31.5
7	5.	15 6	20.6	15.	5.6	20.6	24.7
8	2.5	12.5	15.	7.5	7.5	15.	18.

coefficients marked on the ties and struts in the sketch, and from there the apex coefficients and horizontal strains marked on the panel lengths of upper and lower chords.

In calculating the maximum strains in struts and ties, we use the decreasing series mentioned above, the ratio being 2, that being the number of systems in the truss. Thus, supposing the 12th tie was under calculation, we should have:

$\frac{W'}{L}(12 + 10 + 8 + 6 + 4 + 2) = 26.25$ tons.

This added to 2.5 W = 12.5 tons, gives 38.75 tons for total maximum vertical strain on this tie and corresponding strut. To apply the check we have on this tie, when the truss is fully covered with rolling load, 2.5 W″ = 37.5 tons. The apex between it and the nearer abutment sends $\frac{2}{6}$ W′ = 1.25 tons through it to the farther abutment, making a total of 38.75 tons, as above.

We have, therefore, the following table of strains on ties and struts, beginning at the abutment. (See Table 1.)

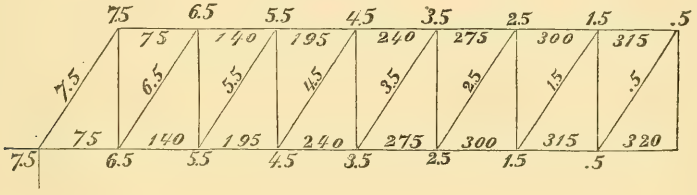
The 5th and 6th columns contain the check calculation, the result of which, in the 7th column, is the same as that of the first calculation in the 4th column. The 8th column shows the actual strain, obtained by multiplication by sec. θ.

The numbers in the first column refer to the ties, counting from the abutment, and apply also to the corresponding struts. The first strut, however, being vertical, does not require the multiplication by sec. θ.

If the truss had been simple, *i. e.*, containing only one system of bracing, the calculation would have been similar, as it would also be, did the truss contain 3 or more systems.

As an example of a simple system of bracing, we have in Fig. 2 the half of a Howe truss; the elements being the same

Fig. 2.



as before; the coefficient and horizontal panel strains are shown in the sketch. The following table shows the maximum vertical strains, observing that the ties, being vertical, should not have their strains multiplied by the secant. Also, that the strain on the centre strut must be doubled for the centre tie, as it (the tie) sustains a whole panel weight, which is divided between the two centre struts. The coefficients are marked on the struts alone, as the ties have no horizontal components.

Table 2.

1.	2. W	3. W′	4. W + W′	5. W″	6. +	7.	8. × Sec. θ.
1	37 5	75.	112.5	112.5	0.0	112 5	135.1
2	32.5	65.7	98.2	97.5	0.7	98.2	117.8
3	27.5	56.9	84 4	82.5	1.9	84 4	101 4
4	22.5	48.8	71.3	67.5	3.8	71 3	85.6
5	17.5	41.3	58.8	52.5	6 3	58.8	70.6
6	12.5	34 4	46 9	37 5	9.4	46 9	56 4
7	7 5	28.2	35.7	22.5	13.2	35.7	42.8
8	2 5	22 5	25.	7.5	17.5	25.	30.
	2.5	....	27.5	25.	2 5	27.5	

In simple trusses like the Howe, these strains are a little in excess of the true maximum vertical strains, as there is always a half a panel weight of rolling load $\left(\frac{W'}{2}\right)$ acting as a subtractive element, but this is omitted, being an error on the side of safety, to avoid complicating the calculation. It can easily be taken account of if required.

It will be perceived that in order not to complicate the figure in the above example, the counter braces are omitted. As the main office of these members is to stiffen the truss, in which service they sustain an uniform strain of one panel weight of rolling load on each counter, they should be calculated to receive this strain without flexure, in which case they will be probably always more than sufficiently strong to re-

sist any direct shearing strain which may come upon them. For instance, in the present case, let us see what direct shearing strain can come upon the counter brace next the centre—which is the one most strained—when the truss is half covered with the rolling load, which is the condition entailing the heaviest shearing strain on the counters. By summation of series, we will find a compressive strain upon it of $28\frac{W'}{L} = 17.50$ tons, and a tensile strain of $\frac{W}{2} + \frac{W'}{4}$ (the rolling load reaching only to the centre, leaves only $\frac{W'}{2}$ on the centre tie, half of which goes to each abutment) = 5 tons. Total compression 12.5 tons, or only 2.5 tons in excess of the stiffening strain.

In the previous example of a double Warren truss, the greatest shearing strain, under similar circumstances, would come upon the strut at the centre, marked with the coefficient 0. This would sustain tension to the amount of $\frac{W'}{L}16 = 10$ tons, against which there is no compression to set off. We have, therefore, a total of 10 tons tension on this member, just what is called for by the stiffening strain.

The above process of calculation applies to all kinds of straight trusses. The only kind of truss likely to cause any difficulty in its calculation is the Post, and some kinds of multiple lattice trusses. These are sufficiently discussed in No. 39, Vol. VI. of this magazine to render any farther notice of them unnecessary.

The following formulas for strains in straight flanged girders, resting on two supports or abutments, and variously loaded, may be found convenient. Some of them are believed to be new:

W = weight = 10 tons in the examples.
L = length between abutments = 12 ft. in the examples.
D = effective depth, = 1 ft. in the examples.

1*st Case.*—Girder sustaining a single weight, at centre.

Horizontal strain, at centre—

$$S = \frac{W L}{4 D}.$$

At a point distant n from nearer abutment—

$$S = \frac{W n}{2 D}.$$

Vertical strain throughout—

$$S = \frac{W}{2}.$$

2*d Case.*—Girder sustaining weight at a point distant p from either abutment—usually taken from nearer one.

Horizontal strain, at point of application, p—

$$S = \frac{W p}{D L}(L - p).$$

At a point distant n from nearer abutment, p being also counted from nearer abutment.

1*st.* When p and n count from same abutment

$$S = \frac{W n}{D L}(L - p).$$

Ex.—Let n = 2 ft. from left hand abutment.
Let p = 3 ft. from left hand abutment.
S = 15 tons.

2*d.* When n and p count from opposite abutments

$$S = \frac{W n}{D L} \cdot p.$$

Ex. Let n = 2 ft. from right hand abutment.
p = 3 ft. from left hand abutment.
S = 5 tons.

Vertical strain. Let $p' = L - p$. Then vertical strain between point of application and nearer abutment—

$$S = \frac{p' W}{L},$$

and between point of application and farther abutment—

$$S = \frac{p W}{L}.$$

3*d Case.*—Girder covered with uniformly distributed load.

Horizontal strain at centre—

$$S = \frac{W L}{8 D},$$

at a point distant n from either abutment, usually taken from nearer—

$$S = \frac{W}{2 D L}(L n - n^2).$$

Vertical strain at any point distant n from nearer abutment

$$S = \frac{W}{2 L}(L - 2 n),$$

or, if $W' = \frac{W}{L}$ = weight per unit of length of girder—

$$S = \frac{W'}{2}(m - n),$$

m being $= L - n$.

The greatest vertical strain comes on any section of girder when it is only loaded from such section to farther abutment. It then exceeds the strain at such section when under uniformly distributed load by

$$\frac{W m^2}{2L^2}, \text{ or } \frac{W' m^2}{2L},$$

W' being as before $= \frac{W}{L}$, and m being the length of the unloaded segment.

4th Case.—Girder loaded with an uniformly distributed weight W, as in previous case, and also with a single weight, W' applied at a point distant p from nearer abutment as in Case 2. Required, the point of maximum horitontal pressure, distant x from nearer abutment, and amount of strain at this point.

N. B. The point of maximum horizontal pressure is that around which the reactions of the two abutments are equal.

$$x = \frac{L W + 2 p W'}{2 (W + W')}.$$

Let $x' = L - x$. Then

$$S = \frac{x'}{2DL}(LW + 2pW' - Wx')$$

Ex. Let $p = 3$ ft. and $W' = 10$ tons.
Then $x = 4.5$ ft., and
$S = 32.8$ tons.

BUILDING IN CONCRETE.

By W. C. HOMERSHAM, C. E.

From the "Journal of Society of Arts."

In the portion of waste ground near the machinery room, known as the Western Annexe, there are four firms exhibiting buildings of concrete in course of erection. As it is intended to carry on the process of building during the next few months, it is only possible to describe the erections as they now are, and it must be remembered that they are from day to day continually changing.

One exhibitor, Mr. Drake, is building a two-story house 12 ft., 6 in. square in internal dimensions, with walls nine inches in thickness throughout. The walls are at present carried up a few feet higher than the level of the first floor, which is finished off, as also are the stairs leading thereto. The steps are very neatly moulded in concrete, and have much the appearance of having been worked out of sandstone. The concrete in the walls of this building is composed of a compound of Portland cement and selenitic lime, gauged one part of the compound (one-third Portland cement, two-thirds selenitic lime) to seven parts of gravel containing a suitable proportion of sand. The stairs and first floor are made of concrete gauged with pure Portland cement and gravel, in the proportion of one part of the former to five of the latter. In the construction of the first floor one light wrought-iron rolled joist was embedded in the concrete.

Another exhibitor, Mr. Tall, has a house 17 ft., 6 in. by 16 ft., on the plan, in internal dimensions, in about the same stage of erection as the one already referred to. In this structure there are no stairs or means of communication internally between the ground and upper floors. The upper floor is completed, and covers the entire space enclosed by the walls. The underside of the upper floor, that is the ceiling of the ground-floor room, is slightly domed. The walls, which are twelve inches in thickness, and the flooring, are composed of Portland cement concrete, gauged in the proportion of one part of cement to seven parts of hard lumps of burnt clay, technically termed "burnt ballast," mixed with sand, for the former, and in the proportion of one to five of burnt ballast and sand for the latter.

There are also a set of six concrete rooms, erected by Mr. Nichols, for the purpose of testing the stoves sent in for the Society's prizes. Though these were not built specially for purposes of exhibition they may be regarded as giving with the other buildings specimens of this mode of construction. It must be borne in mind that the walls have not been faced, but re-

main in the rough state in which they have left the mould.

A fourth exhibitor, Mr. Lish, is showing a material he calls "Tilo-concrete." In this case a single room with door and window is being built, and the material is concrete faced with tile and terra-cotta mouldings. The tiles are arranged in a supporting frame in their proper position, and concrete filled in behind. They are formed with a dovetail or feather behind, round which the concrete sets and holds them fast. The effect is thus produced of a smooth tiled wall. The cost is stated to be about the same as that of the best brickwork. A principal feature of this exhibit is the method of construction employed. At the commencement of the work "guide screws" (in place of the external uprights now in use) are set in the foundation trenches and "plumbed," when the concrete for foundations is filled in round them; after this material has set, these "guides" are screwed up to receive cross-heads, from which the wall panels are suspended. For building ordinary concrete walls plain wooden panels are used, but when the work has to be faced with tiles a skeleton iron panel is employed with rebated bearers to retain the tiles accurately in position until each day's work has set. When one portion is sufficiently set, by means of screws the panels and the platform which rests on them, and serves instead of a scaffolding, are raised, and the work continued as before.

There is one fact noticeable in all the exhibits in a greater or less degree, and that is the ignorance shown by the constructors of the great strength of concrete to bear strains, tensile and other. There can be no doubt that the insertion of the wrought-iron rolled joist in the flooring, of which a plan is given in the figure, is a source of weakness rather than of strength. Portland cement concrete will not adhere to a surface of iron with anything like the same amount of force that the particles of which it is composed hold to each other. In that building also, which is entirely covered with a domed ceiling in concrete, a mistake appears to have been made. Are walls twelve inches in thickness, and nearly as many feet in height, adapted to take the thrust at the top of a very flat arch? Would not a floor of uniform thickness and containing less material (concrete) have been the stronger? To enable the reader to form an opinion for himself on the subject of the latter question, some facts will be hereafter given concerning the strength of Portland cement concrete. A thorough examination of the structure, of which a plan of the first floor is given in the figure, must alone convince the most skeptical on the point of the great value of concrete in Portland cement as a building material, not only for the walls, but for the flooring of every storey and the roofing of houses of every description. The overhanging corner of the flooring at the well for the stairs, in no way supported from below, is quite firm and free from vibration when walked upon or even when jumped upon by two youths of an aggregate weight of over 2 cwt. The floor is seven and a-half inches in thickness.

From the results of experiments made some years since, it can safely be affirmed that the staging necessary for carrying a concrete floor, in green or wet state, of a room say twelve feet six inches in width, by twenty-five feet or any other dimensions in length, may be struck in a week after the completion of the floor if the concrete be only six inches in uniform thickness, and gauged in such proportions that every cubic yard when *in situ* contains four bushels of cement and six bushels of clean, sharp, silicious sand. One month after the concrete has set, the floor would be capable of sustaining an equally distributed load of one hundred-weight per foot superficial, and twelve months after, an equally distributed load of four hundred-weight per foot superficial. If the thickness of the flooring be increased to twelve inches, and the concrete be gauged as above, a room nineteen feet six inches in width by forty feet or any other dimensions in length, may be covered, with the results as to strength the same as those given for the room twelve feet six inches in width.

The roof of a room twelve feet six inches in width may be formed with a layer of concrete four inches in thickness, and that for a room twenty feet in width need not exceed nine inches in thickness. Concrete in Portland cement is admirably adapted for the construction of roofs of buildings; concrete is far less pervious to water than the best brickwork, and when its surface is rendered with a thin coating of compo, gauged one of Portland cement to one of sand, it is perfectly impervious to damp, though it be kept covered with water. The

fact may not be generally known that Portland cement compo has not that tendency to peel off when on concrete in cement, which impairs its efficacy as a facing for brickwork. This is accounted for partly by the surface of concrete (being rough) forming a capital key for the compo, but principally by the far more important fact, that there is no damp in Portland cement concrete after it has thoroughly set. Brickwork absorbs and retains moisture, which, being acted upon by frost, swells, and lifts the plaster from the smooth surface of brickwork. Such cannot be the case with concrete.

Not only is a coating of Portland cement compo valuable on the top surface of the layer of concrete forming a roof, as a protection against damp, but it forms an excellent surface for the flooring of a building. A surface of Portland cement compo resists the action of the tread quite as well, if not better, than some of the superior sorts of stone used for making steps.

The public might here derive great advantage from the practical manner in which the four exhibitors have explained their respective ideas on the subject of building in concrete. The houses they are in the act of constructing will doubtless do much during the season to convince many a visitor that it is possible to construct not only cottages but mansions the most extensive in concrete. A structure composed solely of concrete in the stairs, floors, and roof, as well as walls, is practically monolithic, and not only perfectly water and damp proof, but as nearly as can be conceived proof against the ravages of that all-devouring element—fire. By forming the division walls between the various rooms, of Portland cement concrete, each room will be rendered sound-proof, concrete being an excellent non-conductor of sound. The concrete for the walls of buildings need not contain more than three bushels of Portland cement and six bushels of sand per cubic yard. In critically examining the structures in concrete being constructed in the Western Annexe, the visitor must not lose sight of the fact that the exhibits are made by firms desirous of calling the attention of the public to particular forms of apparatus for facilitating construction in concrete, and not by architects desirous of ventilating their professional abilities in the art of adapting a comparatively speaking novel material to building purposes. Had the case been otherwise, there is no reason no doubt there would have been no drawback to the efforts made by the exhibitors in an architectural point of view, such as there is at present. The surfaces of the walls and ceiling of some of the structures are in the rough state, and exemplify the truth of that which has been stated above concerning the excellent key that can be left on the surface of concrete for a rendering of compo. The inner and outer surfaces of the walls, etc., of the building erected by one of the exhibitors are finished off, and have a very neat and clean appearance, though it must be owned the sight reminds one too much of our suburban builders' style of architecture. The writer has seen some very handsome facework on concrete made by imbedding split flints therein, with the split face exposed. How many lovers of good architecture have walked miles to examine a particularly fine piece of flintwork, such as is to be seen at St Augustine's Monastery, Canterbury, and in many other old buildings in that city? Why should not we of the present generation attempt at any rate to vie with our ancestors in this particular art, if such a use of the term may be permitted? In chalk countries where suitable flints are plentiful, field laborers are generally to be found who have been taught the knack of splitting flints. In places where such is the case, a facing of split flints exceeds but little in cost that of forming a face of compo.

For cottages and outhouses, etc., a very clean and neat face may be given to the walls and ceiling by placing a course of pebbles on the exterior surfaces. The pebbles when their outer surfaces have been freed from any compo that may have passed between them during the time of the setting of the concrete, form a surface that is agreeable to the sight and capable of receiving any amount of relief or ornament in compo, the surface being so admirably adapted to key the same. Little more need here be said on the subject of embellishment in concrete, as there are many members of the engineering, and doubtless of the architectural profession also, who could and would design and build a structure wholly in concrete that would prove as pleasing to the great majority of persons of taste in such matters as if it were constructed with brickwork and stone.

Notwithstanding that the exhibits prove the great strength of Portland cement con-

crete, they present no data on which to calculate the exact strength of any particular piece of flooring or wall. Mr. John Grant, C. E., of the Metropolitan Board of Works, investigated the subject of the properties and strength of Portland cement, and has given the valuable and thoroughly reliable results to the world in papers read before the members of the Institution of Civil Engineers. The first paper was read by Mr. Grant in the session 1855-6, and will be found in the 25th volume of the Minutes of Proceedings of the Institution of Civil Engineers, and a second paper was read in the session of 70-2, and will be found in the 32d volume of the Proceedings.

The following table gives the results of experiments made by Mr. Grant on the tensile strength of Portland cement weighing 112 lbs. per imperial bushel, gauged neat, and also with various proportions of clean, sharp, silicious and other sand, after having been kept under water respectively one week, one month and twelve months, the particulars of which will be found in the papers :—

TABLES OF THE TENSILE STRENGTH IN POUNDS AVOIRDUPOIS OF SECTIONS ($1\frac{1}{2}$ IN. $\times 1\frac{1}{4}$ IN. =) $2\frac{1}{4}$ INCHES IN AREA OF PORTLAND CEMENT, WHEN GAUGED WITH

IN THE PROPORTION OF	CLEAN, SHARP, PIT SAND, AFTER			CLEAN THAMES SAND, AFTER			LOAMY SAND, AFTER		
	One week	One month.	One year.	One week.	One month.	One year.	One week.	One month.	One year.
Neat.....	445	680	1,076	.....	.....	.....	.....	.....	.....
1 to 1.....	152	326	796	97	309	700	114	275	645
1 to 2.....	64	166	607	52	123	458	53	130	533
1 to 3.....	44	91	424	27	58	321	21	68	358
1 to 4.....	22	71	318	.....	32	222	.....	60	244
1 to 5	.....	49	216	.....	21	122	.....	31	166

From the same authority the materials are drawn for the following :—

TABLE OF THE COMPRESSIVE STRENGTH IN TONS OF SURFACES (9 IN. $\times$ $4\frac{1}{4}$ IN. =) $38\frac{1}{4}$ IN. AREA OF

IN THE PROPORTION OF	PORTLAND CEMENT WHEN GAUGED WITH CLEAN, SHARP, PIT SAND, AFTER		
	Three months.	Six months.	Nine months.
Neat.....	65	92	102
1 to 1.....	43	59	78
1 to 2.....	34	47	62
1 to 3.....	24	37	41
1 to 4.....	23	31	38
1 to 5.....	16	26	29

It is stated also in the same papers that the crushing weight of a good stock brick laid on the flat (area about 9 in. $\times$ $4\frac{1}{4}$ in. =$38\frac{1}{4}$ in.) is 34 tons, that of a wire-cut gault brick 33 tons, of a compressed gault brick 35 tons, of a brimstone Suffolk brick 44 tons, and that of a fire-brick 63 tons. A fire-brick though it offers nearly double the resistance to a crushing force that stock brick does, is only as powerful to resist a compressive strain as is a similar brick of Portland cement gauged with double its bulk of sand, at the end of twelve months.

The transverse strength of fixed slabs of concrete in Portland cement may be calculated by the following formula, when the concrete has been made of first-rate materials and thoroughly incorporated with four bushels of cement of the first quality, and six bushels of clean, sharp, silicious sand, per cubic yard.

Let A represent the area of the transverse section of a slab, and D the thickness thereof, both in inches, L the length of span in feet, and W the equally distributed load in cwts. that will cause a rupture in the concrete at the end of a week, after the concrete has been left to set, then

$$\frac{A\,D}{4\,L} = W.$$

The constant is 1-6 in place of 4 for the strength at the end of a month, and 0.56 for the strength at the end of a year.

Example.—What amount of uniformly distributed load will a slab of Portland cement concrete (gauged with 4 bushels of cement, and six bushels of sand per cubic yard), 15 ft. in length by 1 ft. in width, and 6 in. in thickness, bear at the end of a

week, a month, and a year when fixed on bearings 13 ft. apart.

$$\text{Area } (12 \times 6 =) \frac{72 \times 6}{4 \times 13} = 8.3 \text{ cwts. at the end of a week.}$$

$$\frac{72 \times 6}{1.6 \times 13} = 20.76 \text{ cwts. at the end of a month.}$$

$$\frac{72 \times 6}{.56 \times 13} = 59.34 \text{ cwts. at the end of a year.}$$

The weight of the concrete itself often forms an important item in the amount of the load to be carried, particularly when the length of the span or opening is considerable.

Concrete varies considerably in density, but in calculating the amount of the weight as a quiescent load, it will suffice for all practical purposes to take the weight of a cubit foot at 1.2 cwt., which is equal to 0.1 cwt. per foot superficial for each inch in thickness of a slab of cement.

The weight of a six-inch slab of concrete, 1 ft. in width by 13 ft. in length (between the bearings) so calculated is ($1 \times 13 \times .6 =$) 7.8 cwt.

By the foregoing calculations it appears that such a slab after it has been made a week is capable of sustaining an uniformly distributed load of 8.3 cwt., or .5 cwt. in excess of the quiescent load in the shape of the weight of the concrete itself. It follows that the supporting staging may be struck with safety at the end of a week.

At the expiration of one month the transverse strength of the slab is increased so greatly as to enable the slab to bear a uniformly distributed load of 20.76 cwt. in the gross or (20.76—7.8=)12.96 cwt., independent of the weight of the concrete. Again, at the end of a year the transverse strength is further increased, and the slab will sustain 59.34 cwt., uniformly distributed in total, or (59 34—7.8=) 51.54 cwt., independent of its own weight. In other words, a six-inch slab of Portland cement concrete, 1 ft. in width, spanning an opening of 13 ft., is capable of sustaining, after it has been made twelve months, an uniformly distributed load equal to nearly 4 (3.96) cwt. per ft. superficial. To attain uniformity in the strength of concrete, so essential in the construction of monolithic floors and roofing, it is advisable to adopt the French system of mixing, that is, gauging the cement and sand into a compo in the first instance, and then adding clean-washed shingle or burnt ballast, or a mixture of the two, in the proportion necessary, according to the nature of the work to be executed.

Great attention must be paid to the quality of all the materials used in making concrete in Portland cement, even to the water, which should be perfectly clean. The weight of the cement per imperial bushel should not exceed 116 lbs., or be less than 112 lbs., when dropped into the measure from a board fixed, say 2 ft. above the top of the measure. The sand should be rather large-grained, sharp, silicious sand, and must be washed perfectly free from loam or other extraneous matter. The shingle also should be washed free from particles of sand as well of loam and other foreign matters. The thorough incorporation of the cement and sand is facilitated by mixing them dry under edge-runners for a period of five minutes for each portion of sand there is to one of cement before adding the water; thus, in the concrete for the floors, the writer would recommend the compo to be gauged one and a-half of sand to one of cement, therefore it should be mixed dry under edge-runners for ($5 \times 1\frac{1}{2} =$) $7\frac{1}{2}$ minutes. In the concrete for walls if the compo be gauged at two of sand to one of cement, the time of mixing dry should be ($5 \times 2 =$) 10 minutes; and when the nature of the work to be executed is such as to permit of the compo being gauged three of sand to one of cement, then the time must be extended to fifteen minutes.

The prime cost of concrete varies considerable according to the site on which it is used and the nature of the work to be executed. Thick walls of a building in concrete, as in brickwork, are less expensive per cubic yard to construct than walls that are thin. Boundary or garden walls may be constructed with safety of concrete gauged in such proportions that each cubic yard contains only two and a-half bushels of Portland cement and seven bushels of sand.

The public have the advantage of seeing in the exhibits two distinct materials used to form the body of the concrete—gravel and burnt ballast. Both make equally good and strong concrete; but perhaps concrete of burnt ballast is to be preferred for the construction of flooring and roofs. It is both lighter and better adapted to resist the action of fire than concrete of gravel.

The first cost of cottages in concrete, with concrete stairs, floor, and roof, is from 30 to 40 per cent. less than a building of brickwork, with slate roof and timber floors. Besides first cost, the cost of maintenance has to be taken into consideration in determining the actual value of any property. This is entirely on the side of concrete as a building material. There have been many cases where far larger sums have been expended, and fairly expended, in breaking up a piece of good concrete in cement than it cost in making.

To enable the reader to form an approximate idea of the cost of Portland cement concrete *in situ* in a cottage or two-story building, it may be mentioned that the cost for labor of all kinds should not exceed 2s. 9d., but say, 3s. per cubic yard or £1 14s. per rod. The cost of Portland cement may be taken at 2s. 6d. per bushel delivered on to the works, including the cost of testing. The paper read by Mr. Grant before the members of the Institution of Civil Engineers (see 26th volume of the Proceedings) concludes with a most needful warning from the author against the use of Portland cement, by any engineer or architect who is not prepared to take the trouble and incur the expense of thoroughly testing every bulk of cement on its delivery on the site of the works.

First-class concrete for floors and roofs, as has been shown, requires 4 bushels per cubic yard, or 45⅔ bushels per rod, making the cost for Portland cement 10s. per cubic yard. or £5 13s. 6d. per rod.

Concrete of the second class, for walls of buildings, contains 3 bushels per cubic yard, or 34 bushels per rod, the cost of which is respectively 7s. 6d. and £4 5s.

In garden walls and steps for stairs the cost of the cement is only 6s. 3d. per cubic yard, or a little less than £3 10s. per rod. Two and a-half bushels per yard, or twenty-eight bushels and a third per rod, are thus all the cement that is required.

Should there be a pit of good clean gravel handy to the site of the works, to produce the necessary quantities of shingle and sand, the cost of the gravel to make one cubic yard of concrete should not exceed, say 15d., including carting, screening, and washing, that is, 14s. 2d per rod. When the cost of getting first-class gravel on to the ground exceeds 3s. or 3s. 6d. for the quantity necessary to make a cubic yard of concrete, it may prove more economical to burn clay from the foundations of the buildings, etc., and make burnt ballast.

The minimum cost of burning ballast when clay fit for the purpose is found on the site of the works may be put down at 3s. per cubic yard, including the cost of labor in sifting and washing, but not of providing the necessary quantity of water. The quantity of water required for washing and soaking burnt ballast is about 20 gallons per cubic yard, or a ton weight per rod. One half that quantity will suffice for washing good gravel, containing the proper proportion of clean sharp silicious sand; such only should be used in making concrete. The quantity of water requisite for gauging the compo is about three gallons per bushel of Portland cement and one gallon per bushel of damp sand.

This case will prove to be very exceptional where the cost of Portland cement concrete *in situ* in a building proves to be on the average less than 10s., or more than 16s. per cubic yard, *i. e.*, £5 13s. 6d., or £9 1s. 6d. per rod.

In Room 22 of the International Exhibition will be found samples of Portland cement and of blocks of compo thereof gauged neat, that have been tested, and when broken the amount of the tensile strain which broke it may be seen marked on each.

The "testing machine for cement," exhibited in the same room (No. 5,719), is by no means satisfactory; it compares very unfavorably with the excellent, delicate, and well-adapted instrument used by Mr. Grant in making all the experiments of which he gives the particulars in his papers before referred to. In testing with an instrument of the pattern adopted by Mr. Grant, the block of compo cannot be subjected to any amount of jar or vibration, and the exact breaking weight to a pound is registered.

In Room 22 will also be found exhibits of the Selenitic Cement Company (limited) and of that made by Alex. McClean and Company. They both deserve the careful consideration of any person interested in building operations, and particular of those contemplating building in concrete. The "superfine quality" cement exhibited by the latter is very white, and takes a very high polish, as it is exemplified by some of the articles in the exhibition.

A FEW OF THE ESTHETIC PRINCIPLES OF ARCHITECTURE.

By C. A. EVANS, C. E.

Written for Van Nostrand's Magazine.

The principal object of architecture is to build well as regards stability and convenience. Still it extends beyond this point into the domain of taste, and aims at giving a suitable expression to a contemplated structure. A consideration of some of the principles in this latter branch of the art, will form the subject of the following remarks.

Evidently the expression desired must be varied to suit each class of buildings. A theatre should express in its style the festivity to which it is devoted, a house of legislation should appear grand, a dwelling polite, a villa inviting. Such expressions are to be attained, however, without sacrifice of either strength or convenience, and without the introduction of unnecessary features. Success depends mainly upon the education given to the taste; which is most effectually acquired by means of an enlightened observation through art and nature. The rarity of its possession will account for the many failures to produce fine buildings. Sometimes false ideas of what constitutes the skill of an artist, contribute to the same unhappy end. For instance, it is very generally regarded as an index of architectural talent, the ability to make fanciful designs which shall not resemble, either in outline or details, any other structure previously erected. These designs are most always pleasing on paper, it is true; but afterwards, when carried out in stone, they do not give as much satisfaction. As in literature, such exuberances are indicative of more vigor of imagination than correctness of taste. Thought plays in them a subordinate part to fancy, which inspires the whole. The severely pure, in which genius appears at times a little rough, but always very grand, where the art is too deep to be seen, and, still, too powerful not to be felt, is preferable by far to easier and gaudier work.

Taste then, upon which so much depends, is, to a great extent, a child of circumstances. These are greatly determined by peculiarities of race, which in turn are influenced by climate; so that there exists no one standard by which to form taste. Yet it is subject to law, however powerful the influences which tend to modify it, however contrasting the various shades of its character. Who that looks on Grecian art can consider its efforts as either fitful or accidental in their production? The leading principles in these works were derived from nature. The Greeks allowed her to speak; their acts were guided by her voice until their country fell, and had fulfilled its destiny. They studied nature, not as we, by dissecting, classifying, pondering over her economy, but by viewing her with eyes and feelings of artists. The drooping leaf, the lion's mien, the human form, each was to them full of expression. Not content, however, with simply contemplating her beauties, they roused their minds to the search of the principles by the aid of which she gave character to her productions. And they succeeded better both in discovery and applying them than any other race of which record remains. In modern times painters have, as a rule, followed nature more closely than architects. This will appear when we consider that the first works with the concrete and the abstract united, while the second does not, and must separate the one from the other in order to utilize the abstract.

Such a separation having been always attended with great difficulty, and much patience, architects have become accustomed, and indeed, in some measure forced to rely almost exclusively upon the eye and fancy. Though these are guides easier to follow, yet are they also inferior to the teachings of nature. Sometimes from education, often from prejudice, many doubt that architecture is susceptible of any method of treatment different from this usual one. A few others have regarded economy and convenience as the sole objects to be kept in view when designing. As too expensive, therefore, they have banished the Ionic and Corinthian capitals from the art. But a system of architecture which will not permit these capitals being used is indicative of ideas too extreme to find support in those who cling to the chaste and the beautiful. Economy and convenience are fundamental principles in architecture, and the direction in which they point is the correct one. Yet it is not natural for attention to be concentrated ex-

clusively on utilitarian points. The mind seeks instinctively to adorn what it produces. With better judgment, and in imitation of the ancients, others again have applied themselves to the task of investigating the various means which nature employs to give expression.

Foremost among the results of their labors we may notice that, in animals, the idea of str ngth is conveyed to the mind mostly by angularity. When this principle is applied, many sharp contrasts of light and shade are produced. Curvature and roundness on the contrary, are expressive of elegance; and shade, in this case, passes into light by gradation. Reflected curves, so extensively found in the female form, are symbolical of the highest beauty. Round bodies, like the trunks of trees, have an air of strength only when their surfaces are roughened. Hence, in obedience to the foregoing principles, whenever it is desired to express strength, angularity must be found among the characteristics introduced. This object is attained in a design, but only partly, by making the voids and projections rectangular in elevation. In spanning openings with arches their shape is softened; there is gained in elegance what is lost in power. Angularity, though the main characteristic of strength, yet, alone, is not sufficient to denote it fully, and must be combined with breadth. A different practice, by combining height with angularity, leads to majesty; while height with roundness gives elegance in its greatest intensity.

These principles are true to nature. We all recognize that the pine has a different aspect from the oak. The one is tall and majestic; the other broad and strong. The pine stately bends to the breeze; the oak staunchly resists the tempest. And, among the flowers, does not the lily owe its elegance to its slender proportions? In the animal, as in the vegetable kingdom, the same principles reign. The deer we take as an emblem of beauty, and the lion as a representation of power.

According to the preceding, therefore, if we wish to give either to a building, or to a detail a character of strength, we must, besides introducing angularity, intensify breadth. The Greeks understood well this principle, and applied it extensively. They appreciated the opposite principle also, of uniting height and curvature where elegance was desired, though they confined its application almost exclusively to details. There are many features in which height will necessarily exceed breadth. Still, as such features are common to buildings of different characters, variations in their proportions may always be practised, so as to show conformity with the change of expression in the buildings. Columns were thus treated in Grecian architecture; and subject to the same treatment are also balustrades and openings.

Height and intense angularity, when appearing in large features, are productive of a severe majesty of expression. It is evident that no majestic appearance can be given to small details, though proportions in these similar to those in the large features, will be conducive to unity of design, and enhance the effect of the taller masses. By severe angularity is to be understood the existence of right and acute angles, in distinction to obtuse angles. The latter are appropriate to forms less severe, being intermediate in severity between squareness and roundness.

Projection is regulated in severity by the angle at which it juts from the wall. Though most usually this is a right angle, yet, at times, projecting masses make obtuse angles with the walls from which they start. Supported by corbelling, projections lose their boldness to a certain extent, but present, in compensation, a more elegant appearance. The character of the corbelling should be in harmony with that of the projection. Thus, a light corbelling should not support a heavy projection; neither should the corbelling be more massive than the projection. The mass beneath should not pretend to sustain completely the mass above; its office being simply to aid the projection in supporting itself.

Angularity finds its application, to a greater or smaller extent, in all styles of architecture. In some styles it is very decided. To continue angularity to the top, to finish everything square, is the peculiarity of Norman architecture, and the cause of the strength expressed by it. This character of strength is intensified, besides, by monotony in wall, tower, and battlement, and by a regular, though broken elevation, the various portions of which are different in height. In the portions so separated, as well as in the whole mass, breadth must preponderate. This is very essential. But whatever be the other characteristics of a style, angularity, or contrast of light and

shade, should never be wanting. Such contrast is the fundamental esthetic principle of architecture. Gradation follows, and softens, at suitable points, the quick transitions from light to shade. It thus introduces elegance and serves to adorn strength. There are, besides contrasts of light and shade, contrast in size, and contrast in form. We find also gradations of these. But contrast demands two divisions; gradation at least three. Two things may be contrasted, but three are necessary to express gradation.

Upon the principle of gradation depends the practice of placing the lighter forms above the graver. A hexagonal feature is put above a square one, and a cylindrical feature higher than a hexagonal one. Hence the lower portions of a building should present none but grave forms, while in the upper parts the lighter forms may be introduced. Hence the greater number of mouldings are massed in the frieze and cornice, and prohibited almost entirely in the large features at the base. In the Norman style not much gradation can be found, and in some bad examples there is a sudden change from one extreme to the other. But Romanesque architecture presents very often in belfries and towers, gradations of size and form exceptionally well managed. Grecian architecture offers as much angularity and monotony as the Roman, yet gradation is introduced at the same time; for which reason it does not express the immense strength of the feudal piles. Good examples of a partial gradation may be noticed in Italian belfries, made solid at the base for one or two stories, openings are next introduced commencing with a single one and increasing them in size and number as their location becomes higher. So far only is the gradation carried; not beyond masses of light and shade. A more complete gradation would be, to cause the stories to soften in form and change in magnitude with their elevation above the ground. These modifications, however, while producing more beauty, would destroy considerably the majestic appearance of the belfry, due to the long vertical lines extending from the foundation to the roof. The square towers of the Gothic style, when they do not change in shape upwards, are lower than the Italian, and, therefore, have an aspect of great strength and massiveness.

The ancients were well aware of the majesty of tall proportions. Accordingly, we find the openings between the columns high and narrow. Besides their other advantages, the flutings possessed that also of increasing the apparent height of the column. In order to make them prominent they were cut small and close together; in other words they were massed. The Gothic builders, likewise, appreciated the majestic appearance of high features. Indeed, their entire style is but a magnificent embodiment of their love for the majestic. As they improved in their art, higher and higher rose the vaulted aisle. The flying buttress steadied the imposing pile, and the whole stood forth so loftily that it looked like the work of fairy hands. Particularly in their interior work were they extremely successful in carrying out the genius of their architecture. The clusters of pillars which support the walls of the nave and the vaulting above, they caused to shoot upwards, at times, without interrupting their course by capitals at the various tiers of arches. The eye ran smoothly along them to the centre itself of the vault, high over the middle of the pavement. No imagination so torpid but was excited by such majesty. Those elevated vaults could be compared to the heavens only, and the beholder acknowledged without effort the fitness of the building for its sacred purpose. On the principle that pervades Gothic architecture may be constructed many features in other styles. Doorways in which the shafts or pilasters at the sides dispense with capitals, being joined without demarkation to the arches spanning the openings, have their height and majestic appearance increased. A low full centre arch sunk deeply into the wall, has, on the contrary, an air of immense massiveness. The proper employment of this arch is under monotonous masses, not too high, as in Norman architecture. Of this style, it is, evidently, the distinguishing mark. It is well adapted to the lower portion of a high and massive building also, in which position it has been successfully used; but, of course, never with the effect which it possesses in its true position, under broader and lower masses. But to express the majestic, the best arch is the Gothic. Its verticality is decided, even when the opening is not carried high. In this respect it has the advantage over the circular arch. The effect of the introduction of a keystone in a large circular arch, is bad, as the bold sweep of the curve is broken. Keystones are best employed in

narrow arches where verticality predominates. Indeed, narrow full centre arches do not possess any agreeable expression without keystones; particularly when the openings are very high. In addition to attention to arches, we must preserve the corners in a building, should the full effect of its height be desired. Horizontal divisions, if introduced, should be recessed and stopped before reaching the corners, which, in consequence, will be thrown into the form of pilasters.

The ancients never broke the course of the long horizontal mouldings and plain bands, passing from end to end of the entablature. The small repeated figures, such as modillons, dentils, and triglyphs, served to produce variety and to enhance the grandeur inspired by the long continuous features. For nothing will be grand that is not monotonous. The sky and the ocean are familiar examples. The mountains, too, with their long sweeps, are another instance of the grandeur of monotomy. Hence, in architecture, in order to aspire to real grandeur, length and surface, either straight or curved, but unbroken and continuous, must be visible. When repeated features are added, these should recur at *short* intervals that they may be analogous in effect to length. Monotony is thus rendered vigorous, which it must be to appear pleasing. Attempts made to interrupt it by drawing the eye upon something else for a while, will prove fatal to its grandeur. An inclination for novelty will often induce the designer to break his long lines with slight projections, and, sometimes, by a total change in the design, much to the advantage of the picture on the paper, but greatly to the injury of the aspect of the building. A long wall is pleasing, especially if its monotony is intensified, from its being built of stones uniform in size and color. Let a few openings be introduced here and there irregularly, and all its effect is lost. The impressiveness of the Norman tower is owing, in a great degree, to its monotony of surface. Irregular, detached, and variously shaped masses may convey to the mind the idea of picturesqueness, but they are incapable of producing in it the impressiveness of grandeur.

A structure with many vertical projections close together, besides wanting monotony of surface, presents, also, the disadvantage of not being suitable for oblique views. In order to understand the design it is necessary to stand directly in front of the building. No such defect exists in the Grecian architecture. In good examples of the Gothic it is not to be found. The vertical masses there are large and widely spaced, thus giving rise to a distinct arrangement from wherever viewed. Modern architecture, unfortunately, abounds with this fault. According to the present taste, unless a building is cut up with pilasters, projections at the ends, projections at the centre, curves here, and straight lines there, columns between the openings and porticoes never to be used, it is not considered elegant. Instead of attributing weakening effects to such irregularities, they have been attributed to openings. But apertures do not weaken by far as much as little and numerous breaks, which were the characteristics of the most debased style that ever arose. The presence of apertures, by destroying monotony leads, it is true, away from grandeur and solidity; but while disadvantageous in this respect, they compensate for the loss of effect they occasion, by giving rise, in deep walls, to powerful contrasts of light and shade. Something analogous to this may be remarked in Gothic architecture. Monotony and its grandeur, however, has not been disregarded in this style, for uniting under one grand feature the projections and voids beneath, the long masses of monotonous roof in the Gothic cathedral enable the eye to appreciate the great extent of the building. All structures which, like it, are broken in ground plan, may have such monotonous masses at their summits; while those which, resembling the Grecian temple, are compact, may place here play of light and shade, calm monotony being found on their sides. It is evident that the contrast which this practise produces, must contribute considerable to the general effect.

Smooth columns were used quite properly by the Greeks in their Doric order; the monotony of surface being in keeping with the rest of the structure. Of large diameter and comparatively short, with the view of inspiring a sentiment of immense solidity, they were employed also, with great success, by the Gothic builders in interior work. Fluted columns, like those of the Doric order, are appropriate, by reasons of the angularity obtained, to express strength. For the sake of contrast, columns are partly fluted; but wherever the fluting is placed, the lower part of the column

should project beyond the upper part. The greater amount of material should be seen beneath, whether in a column or in a building.

A building being in reality more solid at the foundations than at any other point, its base is the proper location for monotonous wall. As we rise, openings more and more numerous may be introduced and conformably to conditions of stability, the walls may decrease in thickness at the same time. The shapes of the openings, as well as the forms of the other features, may be diminished in severity as their positions are higher. The roof being the lightest part of the structure, it will bear, by virtue of this principle considerable ornamentation. Should the building be of a severe character, a strict monotony of figures, but elegant in themselves, is preferable in the roof to broken masses. This principle, it is needless to say, is well exemplified in the Grecian orders. Tile roofs, the tile being of marble, stone, or baked clay, and metallic roofs, to a certain extent, are the kind which admit of such treatment.

A part not at all inferior to monotony of construction plays monotony of color in producing grandeur. Nature, who always arrays herself in the most fitting manner, employs monotonous coloring in all her stupendous works. Only in shells, in flowers, and in small objects, do we discover the most lively beauty produced with a variety of tints. But when we turn to the mighty dome over us, shining with innumerable lights, we perceive there the same dark, solemn grandeur wherever the eye wanders over the vast scene. As the sun rises this scene changes, it is true, but is converted into another as grand, as magnificent and though less solemn, yet much more monotonous with its unvarying blue. While the change is great in appearance, in character it is slight. Still, combined in a tasteful manner a variety of colors give to a building a vivacious appearance. Such an expression is not suited to an air which, like the grand, requires repose. There is something more impressive in the silence of repose than in the tumult of action. When the sea lies spread out before us, its smooth surface slowly swelling, it strikes us with greater awe than when the storm roars and the waves are lashed into fury.

Besides great monotony and a grand repose, then is to be noticed another characteristic of Greican architecture. This is, the air of massiveness which surrounds it. Even the Corinthian order, graceful as it is, numbers among its attributes a certain tempered massiveness. The Grecian works owe this air of solidity somewhat to their squareness, but principally to their porticoes. Here rows of large columns support heavy entablatures, the solid construction of which is visible from below. No meanness meets the eye; deceit is not practised; every thing shows itself a worthy member of the whole. Indeed the portico is quite as much the glory as the distinguishing feature of the ancient orders. It is composed entirely of large stones; and its mouldings and ornaments, so well chosen and carefully placed, serve to render graceful only a real massivness. We may leave here something from the Greeks. Their work shows the necessity of abandoning the small material used to such a great extent at the present day whenever we desire to reach excellence. The Egyptians went to one extreme in the size of their stones, and we have gone as far towards the other extreme. Particular attention should be bestowed on the sizes of the stones for a contemplated structure. Because when too large they decrease the apparent magnitude of the building; when too small, their effect is lost. In aspiring to the grand it is essential to recognize the necessity for large stones and extended masses. Our skill lies in their treatment only. We may regulate their bulk, dispose them to the best advantage, but we cannot dispense with their employment. Even when these requisites are obtained, we yet need something more to make massiveness fully preceptible. The eye must observe in all classes of buildings the three dimensions. It is evident that depth will never be seen so largely as height and breadth; yet by increasing the number of points where it is visible, that is, by introducing the greatest number of openings consistent with preserving a sufficient amount of plain wall, we are enabled to obtain a strong impression of this dimension. The effect of depth is produced in a Grecian temple, by the decided projection of its details, and the distance which the main building is placed behind the columns. The thick buttresses and the deep portals of the Gothic architecture, fulfil the same purpose. When these buttresses are united to thick walls, the spectator obtains the idea of a much greater massiveness than really exists.

Ornaments, whether as projecting members, or as detached ones, contribute, in all cases, to augment depth. They may be regarded as essential features ornamented; and while this definition is in the main correct, yet, when we descend to minor decorations it is not applicable to them. The avowed object of many of these is to ornament, by varying at suitable places the *nature* of the monotony. Such features are not those which will be here considered. Larger ones, intended for utility and designed with such an object in view, will claim our attention. The most important among these are corbels and columns. Corbels and columns appearing to support something, but in reality upholding nothing, are evidently unnecessary, and should be omitted. If it is designed to introduce them, and the style of the building will allow of their use, the construction should be designed in such a manner as to make them fulfil needed functions. Columns in openings should aid in supporting the lintels and masses above them, they are ranged over one another along the stories of a structure, they have the plausibility of being necessary adjuncts, though really the projection of their entablatures may not be so great as to require support, and even these salient masses themselves may be useless. This practice, borrowed from Venetian architecture, is pursued confessedly for the sake of adornment. Not understood in its management, plain wall is supposed to be ugly, and its employment is to be avoided. But neatly constructed, particularly when of ashlar masonry, it is in itself a decoration full of chasteness of the highest order, and preferable to ornaments fastened on. Needless columns placed against buildings which they are intended to embellish, betoken a rude taste. It would seem as if transported with admiration for the beautiful features of the Grecian style, we wished to employ them in our architecture regardless of reason and suitability. Hence they appear there as appropriately as would the Grecian costume in our streets. Columns find their true use in porticoes and arcades. From time immemorial they have been thus employed. To stretch their application to the utmost, is to make them intrusive.

The slender pillars seen in doors and windows, are features different from columns in a façade. These shafts aid in supporting the mouldings above, of which they are indeed a continuation. It is not difficult, however, to conceive columns blending into mouldings at these points,

All mouldings, and, generally, all ornaments having beauty for their attribute, should be curved in outline and irregularly curved instead of regularly curved. In other words, the curves should be arcs of ellipses and not arcs of circles. The principle of contrast in its fullest application, should govern the design of a combination of mouldings. No two mouldings, or plain bands of equal height should be visible in the same portion of the building; nor should a moulding and a plain band of the same breadth be united. As a usual rule, two mouldings ought not to succeed one another without the interposition of a plain band. The Grecian mouldings being more angular than the Roman, are more appropriate than the latter for expressing strength. The Roman mouldings are better adapted to express elegance, as they exhibit much more gradation and are softer than the Grecian. Sharp changes from light to shade, introduced both by the Greek and Gothic architects, were not appreciated by the lovers of magnificence on the banks of the Tiber. It is in combinations of mouldings designed upon the principle of contrast, where acute angles find their common use, which is to give intensity to the play of light and shade. Plain bands, in consequence, are not numerous; but their complete prohibition is not allowable.

Mouldings are employed to separate features and to indicate change of form in the features themselves. As a protection to joints beneath, they are extremely valuable. The play of light and shade which they present is an agreeable property; so much so, that it may be compared to the melody of music. In order to make such play distinct, it is necessary to have a light colored and fine-grained material. Hence the superiority of marble over all the other varieties of stone. Darker stones, as may be imagined, require more light in proportion to the obscurity of their color, to produce a play of light and shade equally strong. In this respect the ancients had a great advantage over the Gothic builders; both erecting their buildings in open sites made the difference more marked.

Interior mouldings, to have their greatest effect, must receive a sufficiently strong light to bring out the shades, shadows and brilliant lines in a preceptible manner. Where this amount of light cannot be ob-

tained, no great effort should be made to attempt such decoration.

In studying the orders of the ancients, there is to be remarked not only the prominence of their ornament, but also the system which they followed in its distribution. They placed in it masses, which they separated by other masses of plain work. Indeed, plainness and ornamentation succeed each other regularly all the way up the structure. Ornaments are condensed at the bases and capitals of the columns, and the shafts remain plain. In the entablature, the architrave is divided from the frieze by a prominent moulding; and the frieze is left smooth to contrast with the mass of ornament in the cornice. Though decoration was massed, yet it was another principle of Grecian architecture never to confuse the eye by too much. This principle also the Romans do not seem to have understood. In many of their designs we are bewildered with the amount of gorgeous work covering every part of them. The eye cannot follow such extended successions of different figures, however beautiful in themselves, for it needs plain wall upon which to rest. Generally, excessive ornamentation may be regarded as an indication of decay of taste, in all the arts and in none of them more so than in the building art. Instead of ornaments being borrowed from various styles when needed, they should rise from themselves in every piece of work, springing naturally from the treatment of the subject, after it has been planned to fulfil its purpose. An architect of the present day when designing, is often apt to consider how a certain ornament would look at a certain point, and, if he is favorably impressed with its effect, he will make room for its introduction. A large room may be disfigured, a wing, an entire story may suffer, still he persists in its use, as if buildings were built for their decorations. Most commonly, again, ornament is located with the view to destroy plain wall. This is improper; indeed it is vulgar. Like a person of bad taste, the building will be decked out with too much finery.

On farther study we notice still another principle of Grecian ornamentation. All mouldings in the entablature, and in the capitals of the columns lean towards the front. This is a very natural disposition. For, as the spectator looks up to them, they display themselves to the best advantage to him. They raise in this manner a certain feeling of sympathy between him and the building. The Grecian temple, grand though it be, possesses in an eminent degree this peculiarity; this heightening of its attractive nature; this banishing of every thing repellent. A similar principle to the foregoing governs the disposition of the mouldings in the lower parts of the building. Here all are inclined to the horizon, and, therefore, placed conveniently for our inspection. It is upon this principle that the bases of columns are more pleasing when their spread is decided, than when it is slight. Besides, an air of stability is given to structures and their features, by so arranging the projections at their feet.

Arches are features admitting of much more decoration with mouldings than any other parts of a structure. They have not been always adorned in this manner; but when embellishment has been attempted otherwise, failure has occurred oftener than success. The full centre arch, as used in the early Italian churches, at the sides of the aisles, does not possess the striking appearance of the Gothic arch. This is owing, not to want of massiveness, but to an extraordinary amount of ornament induced through false taste. As an exception, however, the magnificent full centre arch at the altar, extending over the whole width of the nave, has a boldness not found in the pointed arch. Wherever the quantity of ornament at the sides of the aisle has been diminished, the improvement is very perceptible, and the beauties of the circular arch become then prominent. San Marco, Venice, is a good example of the characteristics of this arch. There, massiveness, and no mean height above the floor, add grandeur to its bold sweep across the spacious aisles. The habit so persistently pursued by many ancient architects, and still followed by many modern ones, of ornamenting the soffit and heads of the arch with sunk panels decorated with mouldings, and sometimes with rich carvings, rob it in wide spans of its true beauty. In place of this treatment, it is preferable that the ringstones be finished on the sides with an architrave, as was in part the custom of the Romans, or the soffit be flared and filled with a mass of uninterrupted mouldings, like in the Gothic arch. Again: too much plain wall over arches seems to overload them. Such practice is, in reality, placing the most solid portions of the construction

at the top. This also is a fault found in the Italian churches, but one which the Gothic builders with their arch very seldom committed.

Columns may support arches where there is a vertical pressure only; for instance, in a vaulted interior, or in a colonnade. Where arches transmit an inclined thrust, solid masses are the proper supports. These are often supposed to be ugly, and several columns are grouped together instead; thus offending against the principle which teaches that fitness for a purpose is the first recommendation for use, and that skill in art consists in giving a suitable expression.

Though Italian architecture in general exhibits a variety of styles joined together without regard to gradation of form, severe forms being often placed above the most light and graceful ones, yet it has depth, masses of ornament, plain wall, and, particularly, handsome arcades. Arcades are beautiful features, and deserve preservation in our modern practice. In Gothic art they may be seen sometimes on the exterior, sometimes in the interior, appearing usually exquisitely worked, though now and then their style is severe. Arcades, and likewise porticoes, unless they are to be of use, should never be built. Many structures have costly porticoes, which on no occasion fulfil their functions, and are intended solely as huge ornaments. Reason revolts against the employment of these useless adjuncts, and dictates, instead, that no buildings save those in which large crowds assemble should have great porticoes. City structures are here alluded to; in the country porticoes have a larger field of application. Arcades may be introduced at every alternate story, or confined to a single one in the upper part of the edifice. When on the ground floor, they appear best projecting from the face of the wall. For recesses, they give an air of insecurity to the whole mass above, which seems upheld by feeble, detached supports. The great depth, however, produced by an arcade so situated, is very effective, and compensates somewhat for this disadvantage. When half recessed and half projecting, an arcade on the ground floor assumes a character and an effect derived equally from one entirely recessed and one entirely projecting. No disagreeable impression is received in this case, as the eye cannot judge very well as to how much is recessed; indeed, it does not dwell here at all upon this point. Nothing is more disgusting than the inaccessible shams often stuck on a façade, and called arcades, though their obvious purpose is ornamentation. Real arcades are useful recesses, revealing the massive walls into which they are generally sunk.

Next in importance to arches, and often connected with them, are pilasters. They were correctly employed in the early churches of Italy. We see them there formed by making panels in the solid work, leaving always a portion beneath untouched to serve as a general base. In most instances they were placed above the eye, in the upper portion of the building, where less solidity was required, and occupying at times more, at times less than one-half the height of the entire structure. Pilasters, and shafts as well, when placed over one another in tiers, should have no bases, but should pass through capitals not very prominent. Properly grouped in a vaulted interior, pilasters give, by their angularity, an appearance of immense strength to the construction. This style may be seen exemplified in a few European cathedrals, built before the Gothic had become the prevailing style for church architecture. Sometimes the interior was made still more severe by the almost complete avoidance of mouldings, so that the angles in the vaulting were left without any ornament, and showed clearly and sharply. Pilasters may be observed grouped like Gothic shafts on the exterior of modern buildings. Such grouping of them is in bad taste, for they are features too severe to admit of graceful combination of round and slender shafts. They, however, may find considerable use suitable to their character, in strengthening the corners of edifices, the junctions of their walls, the sides of openings, and the walls themselves immediately under the roof-trusses.

It is a common practice when using pilasters in connection with columns, to give them the variable batter of the columns. Notwithstanding the authority which may be cited in suport of this custom, it is not correct. Pilasters are entirely different from columns. One is high and angular; the other equally lofty, but round. Pilasters are of a severe, majestic character, while columns are eminently graceful and elegant; attributes which, undoubtedly, may exist in them with more or less intensity, but never completely suppressed. Therefore, the gently curving batter of the col-

umn is not admissible in the pilaster. If a diminution in the latter is desirable, then it should be in a straight line.

We have still another application of the pilaster. It is seen in Moorish art. There semicircular properties are divided into pilasters, and these are connected at their upper ends with arches, which often intersect one another, sweeping alternately from pilaster to pilaster; thus forming a very appropriate decoration, not only for such feaures, but also for complete circular towers of elegant proportions.

The site of a building may be considered as influencing to a certain extent its ornament. Both the Greeks and the Romans appreciated the noble effect of a site on an eminence. For the building shares the grandeur of surrounding nature, and at all points of view forms the central figure in the scenery. It has, besides, a commanding appearance. These characteristics demand consideration in making the design. More attention is to be bestowed on the proportions of masses of light and shade, and of large features than on small ornaments, which evidently will not be prominent. Still the mouldings should be larger than if the buildings were subject to closer scrutiny. But the beauty of the structure depends more on its form than on its adornments. When commanding sites do not exist or cannot conveniently be established, free and open sites are next in preference. All efforts to aspire either to the great or to the beautiful in architecture will be futile, when, as in the streets of a city, the designer is limited to one, and at most, two façades. A building should stand a unit in a space sufficiently ample to furnish points of view from where good perspectives may be obtained. Though this subject should involve the purchase of adjoining properties, yet there need be no hesitation in pursuing this course with public buildings of importance. When circumstances will permit, an opposite course may be followed, and the size of the intended building may be contracted.

Structures extremely ornate, in particular, should stand in open situations in order that the eye may take a position far enough away from them to take in the whole at once, and comprehend the design. For the multitude of objects seen at close inspection divert the attention from the mass to its features, from the features to their details. Hence we may perceive why grand effects are best produced with simple masses. Simple plans also are necessary for grandeur. Complicated ones, besides being bewildering in their effects, exhibit a *few* only of each kind of feature adorning the structure, while the total number visible is considerable. On this point Grecian architecture has an advantage over much of the Gothic. Whatever be the variety of features introduced in a design, they should be gradated in prominence. This is mainly effected by placing them on different planes. Often buildings standing in open sites, and otherwise well designed, fail in this respect, and confuse the eye. In each portion of a building, some one feature from among those used should occupy the first r nk, and the remainder should be subordinate to it in a strongly marked manner. Many features, therefore, will not be admissible. Indeed a few well designed and well placed are all that good taste has ever employed.

Elevated objects, such as domes, with no background but the sky, appear smaller than when they are viewed against a mass of clouds. Similarly, a large edifice standing alone seems smaller than when surrounded by other buildings inferior to itself. The Pyramids furnish an illustration of this fact. A compensation for this loss of size, however, is found in the grandeur acquired. Such being the attribute of a great building so situated, we should choose those ornaments which will be most in harmony with its character. Regard must be had to the following general principle: That it is impossible to combine all the beauties in a single edifice, that a choice must be made of those suitable to its site, and to its character, while the rest must be omitted entirely. This is Nature's method of proceeding. Hence have arisen the various expressions which are displayed in her works.

In preparing a design, proportion must first be given to the outlines of the parts, both great and small, before ornamenting is undertaken. Apparently the simplest, the proportioning of the work is in reality its most difficult portion, and the greatest art is here required. Convenience, proper economy, and finally, a suitable appearance, must be all consulted. Time and labor in no small amounts must be often expended to succeed in realizing these various objects. After everything has been determined to fulfil the first two requirements, convenience and economy, then attention may be given to appearance. The breadths

of horizontal features are to be regulated partly by their lengths, partly by the altitudes of their situations. The higher a moulding, the larger must be its size, and the more sharp its curvature, to be as distinct as those placed at the base of the building. Obscurity of situation, and color of stone, enter also into consideration. A horizontal feature which may show very plainly on a short façade, for want of sufficient breadth, may become indistinct at the farther end of a long one. All proportions on a design should be corrected either by perspective drawings, or better, by large models where light and color may unite their influences. In these models the real prominence, and the relative sizes of all features are properly perceived. It will be found that all horizontal projecting members, such as cornices, will appear narrower on paper than in reality, and all vertical members, such as openings, will, similarly, seem higher in design than in the building.

When proportioning openings we may give them any of the following expressions, choosing according to the character of the structure: They can be high and majestic, or they can be square and massive. A mean between these two is not particularly expressive; though sometimes it may be the form proper to employ. For buildings of a single story any one of these proportions may be used, provided, always, it is in harmony with the rest of the design. In constructions of two or more stories, square openings should be below tall ones, and above the latter may be those of a less decided character. Uniting the windows of two stories into single large ones, is an expedient quite common to produce high openings. The practice is hardly allowable; for it attempts to deceive by making two features *look* like one.

The ancients made large single apertures twice their breadth in height. But when several openings occur side by side, this proportion must be exceeded. In three windows placed together, each must be about three times its breadth in height, in order to produce a striking impression. This proportion should be increased still farther as the number of openings augments.

When many windows exist, as along the stories of a façade, they may be joined horizontally into groups of several, and these groups treated as just noticed. The joining of several windows into one large one, contributes towards magnifying the size of the building, and giving it a character for grandeur, by producing large masses of shade. To heighten the effect of these dark masses, they should contrast with as large masses of light, or plain wall, and, besides, the openings should be deep. At the same time, it is to be borne in mind, that the expression of a front may be destroyed by spacing the windows too wide apart. The width of plain wall between windows should not much exceed the width of the windows themselves, measured from out to out of the projections at the top. Otherwise the openings will be scattered instead of massed. This is a defect not so apparent on a wide front which contains a number of openings, as in one where there are only a few. Care must be taken, also, not to run into the opposite extreme, and place them very close together; giving to the building, in this way, the appearance of only rows of windows piled over one another. In buildings requiring the greatest quantity of light procurable, the openings must be close to each other, and as shallow as stability will permit. Structures of this description, however, are devoted to trade and manufactures, and should be designed with no other pretensions save those of economy and convenience. To endeavor to decorate them, while their construction does not admit of decoration, is bad taste. When neatly, solidly built, and with due regard to the foregoing principles, their architecture is complete. To ornament all buildings, whatever their character, diminishes the power of ornament. We become satiated with the sight of it, and when viewed elegantly disposed, it does not impress us with the force it should, though we may not be insensible to its charms. It is not natural for everything to sparkle. The birds are not all of brilliant plumage; nor the animals of equal nobility in aspect.

In order to produce effective means of shade, windows should be large when occupying prominent positions. Neither an expression of grandeur, nor one of beauty, can be given to a façade dotted over, like a die, with little dark spots. Unlike horizontal repetition, upward repetition is not agreeable, and windows placed above one another should not be exactly of the same height. A great difference in height, also, is not to be introduced, unless it is desired to convey

the impression of the upper floors being inferior to the others.

It is a principle of architecture, one conducive to stability and indicative of order, that voids should be over voids, and projections over projections.

Somewhat analogous to this principle, is that which demands symmetry in plan and elevation in all great buildings. That symmetry is pleasing nobody doubts, but that it is one of the highest beauties few admit. Nature has employed it, however, in forming her most beautiful kingdom. Indeed, the animal kingdom might be distinguished from the others by the perfect symmetry only of its subjects. In the kingdom below, in the vegetable, there is not found symmetry in large objects, but regularity instead; while in the mineral kingdom even regularity has disappeared. Therefore, unless circumstances oblige a structure to be designed on an irregular plan, efforts should be made to procure symmetry. Picturesqueness has charms, but undoubtedly it owes them in great part to its novelty. The best specimens of the picturesque show the masses united as themselves symmetrical; care is taken that they shall be so, and their union is marked in a strong and distinct manner. Many designers, not perceiving this fact, have thought that picturesqueness meant the combination of all kinds of irregularity. Hence the variously shaped openings, and the concealed entrances, and the lopsided towers, and the other absurdities which meet our eyes rather too frequently, it is to be deplored.

Next in importance to the windows, is the base of a building. By the base of a building is to be understood that portion of the foundation walls carried above the ground level, and upon which the building proper rests. It is generally a little larger in plan than the structure, and it may be built either in offsets or with a batter, and quite fitly of rough-faced masonry. With the exception of the angular projections on the faces of the stones, no other indication of irregularity should be visible. The stones should be well proportioned with respect to the size of the structure, they should be chamfered, and they give a finer appearance to the courses when of a uniform depth. The base of a building corresponds to the foot of a column; but, like the foot of the Doric column, it may be omitted. Bases are peculiarly appropriate to buildings in which horizontality or strength predominates. Structures where verticality or majesty is visible may well dispense with them as unnecessary features. This principle was observed to a certain extent by the Gothic builders, who usually made their bases low; and if, in some prominent instances, they placed their cathedrals on bases considerably elevated, their example is not to be followed, particularly in that part where they cut through them with their portals. Unless a base assumes the character of a lower story, it should have as few openings in it as possible. They may be arranged sometimes so as to be invisible in projection.

Though a base is a distinctive feature of a structure, yet, as already noticed, it does not form a necessary one. Nature presents examples in trees and in mountains of bodies without clearly marked bases, and she also presents instances of the contrary in animals. But we distinguish this difference between the two cases: in the former case the mass diminishes as it rises, while in the latter case it increases. Buildings heavily finished at top, and with bold projecting masses at many points, should, therefore, have bases. Those buildings which recede horizontally as they rise do not need them. Small features may have bases or not, according to the taste of the designer. Members like columns and balusters, which tend to uphold something, should spread out at their tops, in order to give a firm seat to the mass supported. It sometimes happens, as in slender shafts, that both bases and capitals are necessary for strength and stability.

As to proportioning the stories of a structure, this is done upon the principle previously noticed in connection with the proportioning of windows. They should diminish gradually with their altitude. Besides, elevation is not exaggerated by division into equal parts, but rather into unequal ones well gradated. Such a division of the stories of a building, or of the similar parts of any feature, adds apparent height by increasing the effect of the perspective. The gradation should be according to a geometrical series. An arithmetical series does not introduce sufficient contrast, and is, therefore, not productive of much beauty. When several bands, plain or ornamented, are placed successively above one another, but in different planes, they should be gradated in breadth according to

an increasing geometrical progression, if occurring at the top of the building, and in a diminishing geometrical progression, if situated at its foot.

We pass now to a principle of architecture often violated. This is unity of design. The observance of this principle requires that either horizontality or verticality shall prevail everywhere in a design. It demands, also, that if arches are used to span the larger openings, the lintel shall be completely excluded; and the reverse, that if the principal openings are rectangular, all the remaining ones shall have this shape. Should some windows be in pair, no single window should be introduced on the same level, and if possible, not used at all. Again, several forms of roof are prohibited on the same building. The architraves of all openings should be similar. Likewise, all projections should be either supported or unsupported. High towers require high coverings to produce harmony between the two parts; though to low towers abrupt terminations may be given. Italian belfries offend against this requirement, and, on looking at them, we are sensible of something ungraceful about their summits. Horizontal divisions on a tower may destroy to a certain extent, its verticality, so that, in this case, flat roofs may not seem very inappropriate. The spire, so extensively employed by the Gothic architects, is, undoubtedly, the most elegant method of terminating a tower.

A design having projecting masses either at the centre, or at the ends of its façade, requires particular attention to maintain unity. The belting at the base, between the stories and at the roof, should run all around the building. Where verticality is intensified, these bands may have their courses interrupted. The windows in the projections should be the same as in the other parts of the structure; when this cannot be the case, they should have a similar shape, and a height equal to the others.

A building designed with a regard for unity, and in which breadth is expressed in all its parts and features, is indicative of great strength; while one in which the masses are higher than broader, being so proportioned by vertical divisions, conveys to the mind an idea of majesty. The majestic expression seems the better one for structures which, like the Gothic, have a very broken ground-plan. Long buildings in which verticality is introduced admit, also, of the effect of multiplicity in a great degree. Bristling with pinnacles and buttresses, and windows, Gothic architecture is peculiarly multiplex in character. Indeed, though multiplied objects may be introduced in a greater or a smaller number in all styles, yet never as effectively as in the majestic style. Multiplicity in the form of alternate repetition, is a characteristic of Grecian architecture. In their courses of masonry, and in their ornament, the Greeks were extremely fond of using it; but, still, confining it always to details of minor importance. It is, no doubt, a happy arrangement, and may well be practiced in our architecture when the elegant, more than the grand, is desired. It finds its application wherever there is a series of features equal in form and purpose. The expression of strength can be given to buildings, the ground-plans of which, though somewhat broken, yet are perfectly simple, regular, and composed of large masses. A structure of a compact form is, however, the best suited for this expression. But, in all cases, before adopting it, the designer should know first if circumstances will permit the height of the building being limited accordingly. Of course, the extent of the structure influences such a consideration, though in an open site, out of a city, this is a secondary matter.

While it is desirable to employ either horizontality or verticality throughout, still there is nothing to prevent us from following the practice of the Greeks, and unite one with the other in the same building. Both should not aspire to an equal prominence; but one must be subordinate to the other, and massed along a suitable part of the structure. In Grecian temples the columns with their openings and flutings are all in one place, and visible at one view. In Italian palace architecture we have another instance of the correct combination of horizontality and verticality. The lower story serves as a base to the upper ones, and is horizontal in its character; while the upper ones are thrown, by means of high and bold pilasters, into a single feature, in which verticality predominates. Buildings of several stories, similarly, should exhibit horizontality beneath verticality, the former denoting much more massiveness than the latter. And when this practice is pursued care must be taken not to destroy the horizontality with vertical projections, nor the verticality with horizontal projec-

tions. This is a great fault of modern art. More than one beauty in one place is an idea fatal to all true decoration.

Among the many features which claim attention with respect to unity, the oblique line, perhaps, is one of the most important. Its inclination is regulated solely with the view to increase the effect of either the height or the breadth of the member to which it serves as a limit. The Greeks could not have been ignorant of the fact that a triangular truss is stronger the greater its rise; particularly, since they made it support, in their roofs, heavy coverings of marble slabs. Yet they did not avail themselves of such knowledge on account of the more pressing necessity which existed to intensify breadth in the pediment, in order that the structure might preserve its unity of expression. With an equal regard for the principle of unity we behold the Gothic builders raising the pitch of all their coverings. Throughout their entire style, in the details as well as in the masses, nowhere does an oblique line occur which is not inclined at a considerable angle to the horizontal. Nothing, indeed, can give so much character to a building as unity. Structures of several stories are greatly improved in expression, when to a variety in the size of similar features, and even in their form we perceive united a resemblance which reminds us that such members are in harmony with one another, and are all parts of the same whole.

An entrance should be in proportion to the size of the building. A large edifice requires a correspondingly noble entrance. When the second floor is the most important one, a flight of deep and wide steps should lead to it. Modern steps are too shallow to be compatible with many buildings to which they are attached. The steps used by the Greeks were in some cases slightly too deep; but the error was in a good direction. Unless entrances are in the form of porticoes, they ought to project very little beyond the face of the building, when imbedded in massive walls which are to be displayed. In the finer efforts of the Gothic artists this principle is exemplified. At the same time being desirous of heightening the majesty of the portal by enhancing its size, they carried up the projecting portion high above the opening.

In adorning a building, the mouldings should be larger, more angular, and joined to deeper and more abrupt recesses on the outside than on the inside, where they are smaller and exhibit a greater amount of gradation. For distant views, as has been mentioned, large and well contrasted ornaments are necessary, in order to make them seen as far as possible. Though mouldings are not rigorously prohibited at the base of a building, yet, like in the Doric temple, we should limit them greatly in size and number. This is not often the case, however, in Gothic architecture. The arrangement of vertical mouldings, and the grouping of pillars around central piers supporting vaulting, should be governed by the principle of contrast. The repetition of the same moulding in the deep recesses of the Gothic arch, is to be noticed, with its tendency to exaggerate the thickness of the wall. In the better examples of the Gothic style, the ornamentation, including mouldings, is confined almost exclusively to the interior; while on the exterior a great amount of large angular masses are to be seen. The propriety of this practice becomes evident when it is considered that ornaments are minor features, not suitable for distant view, and, therefore, never as important as the disposition of the light and shade. Indeed, when angularity is required principally on the outside, and curvation can be introduced effectively inside, then both will be the most advantageously placed. The decline of Gothic art was simultaneous with the disappearance of this principle. In all its great works, the student observes with pleasure how ornament was sacrificed to real grandeur, how vigorously horizontality was made subordinate to verticality. Where a modern designer would carry his mouldings around, as at buttresses, the old cathedral builders stopped them abruptly. In ancient art we notice the contrary, how unbroken are the long horizontal lines. What grace would a Grecian temple have, designed according to the taste of to-day? It is often imagined that simple work, however expressive, requires no art, and that where the eye is confused with a multitude of forms there must be much skill. This is, unfortunately, an opinion too prevalent. Things apparently the simplest, which seem so easy of execution that the novice flies with eagerness to imitate them, but, as in catching the will-o'-the-wisp, to have only a weary chase, are the work of real genius in all branches of art.

Superior to all ornamentation by mould-

ings, is that with statues. However few the carvings and mouldings about a building, if rich in statues, it has a beauty noble and attractive. Under the genial sky of Greece, statues may be exposed to the weather without injury, but in a humid northern climate a different practice must be followed; they require to be placed in niches, or under protection, and a lesson may be learned on this point from the Gothic architects.

Having discussed the more important esthetic principles of architecture, we shall now pass to consider their application. For this purpose buildings may be divided into several varieties, varying in the severity of their treatment. It is plain that verticality and horizontality are independent of such a classification, and thus there is obtained the scope necessary for classifying under a few heads the many styles which abound in architecture. Further, to each of these styles, independently of the others, the same classification may be applied; indeed it marks the changes they have undergone during their existence. In the Gothic and Grecian styles no difficulty impedes its application. This premised, we shall commence with the expression requiring the most severity in its treatment, which is that of grandeur.

In order that a building may appear grand, it should be large; contrast must be introduced to a great extent, and gradation visible in the small features only. The large masses, therefore, ought to be angular, while the openings must be covered by lintels. Prominent ornaments should be used sparingly. A few large mouldings, and as many small ones, may be introduced, but no more. The cornice alone, if one is needed, should exhibit a great contrary flexure. The rest of the mouldings should approximate nearer to the Grecian than the Roman type. It is necessary to imitate nature, and present, either on the walls or on the roof, strict monotony in extended masses of plain work; taking care, at the same time, to have properly disposed masses of shade, of lines, of ornament. Large stones only, well proportioned, should be visible. Depth in openings is absolutely needed, and its effect must not be enfeebled by any attempt to diminish the intensity of the shade. Hence the sharp edges of the openings should be preserved. When it is feared that the openings are not sufficiently deep to produce the intensity of shade required, then bold projections may be introduced. These are readily obtained in a structure characterized by verticality. In one where horizontality prevails, the method of producing them is to give the cornice a decided boldness, support it with no corbelling, and treat in the same manner the upper projections of the openings. Instead of making the outer surfaces of these projections perpendicular, to increase their bold effect they may have, with their mouldings, an inclination towards the front. This practice has been previously noticed in connection with the disposition of mouldings, and other effects besides have been attributed to it. Architraves, if used at all, should be plain. Pilasters introduced at the corners of the edifice and at the junctions of walls, where horizontality prevails, should be designed quite broad. Balusters, likewise, should have their breadth intensified.

A large building, to be surrounded with an air of extreme severity, and not to show any great attempt at refinement, must be massive, contain large extents of plain wall, and, to enhance its massiveness, must have its openings narrow, not high, and deeply recessed. When curvature is introduced either in the masses or in the details, it tends to soften somewhat the severity; though combined with breadth, as in Norman architecture, experience has shown that it is adapted to the severe. Symmetry such a building needs; as well as order in the arrangement of the openings. No moulded cornice, and no ornaments without use, should be employed. In case columns are used, they ought to be heavier and plainer than in the previous style, resembling more piers than columns. The severe, and not very inviting aspect of this style, and also its great massiveness, causes it to be well suited for the architecture of punitive institutions.

On a similar principle elegance should be the characteristic of all places where the mind is to be cultivated. But elegance in a building is, of all expressions, the most difficult to attain. The projections, though decided, should not be so prominent as in the grand style, and when as large, should be supported with corbelling. The openings may be either arched or not, tall and ornamented. Gradations ought to be frequent, and reflected curvature may be introduced in the corbelling and mouldings. Masses of plain wall and of shade are still

necessary, but not as extended as for expressing the grand, which fact will give, consequently, more room for ornament than in that style. Still, ornament should be introduced neither sparingly nor in profusion; it should be employed in judicious quantities, and wherever placed, as usual, it ought to be massed. Elegance has been obtained, like in the Ionic order, with little ornament. When designing this expression, it is preferable to feel as if sufficient ornament has not been used, rather than to imagine that it can bear all which has been put on. Smooth, finely fluted, or reeded columns are very appropriate here.

The difference between the elegant and the ornate lies not only in the amount of decoration, but also in its character. That of the ornate style should contain more curves of double curvature, while carving may be introduced at various points. All openings permit of being surrounded with elaborate architraves. Gradation in their forms may be practiced, like in the elegant style; but, when desired, the apertures may all be light and semicircular. The principle of contrast of light and shade, that is, of depth in openings and recesses, should be still kept in view, if the ornament is to possess distinctness and the building vivacity. To aid in promoting these effects, plain wall should be preserved in sufficient quantities. When a cornice exists it may be richly ornamented, but never so much as to destroy alternation between decorated and plain surfaces.

In villa architecture, where a polite air is to be given to the building, order, neatness, and small ornaments only, should be introduced. The most important considerations are, proportion, unity, play of light and shade. The height of the stories, that of the roof and the sizes of the openings, these influence greatly the appearance of the building. Surrounded by the gay aspect of nature, villa architecture is the proper field for the picturesque. The undulating ground, checkered into squares colored in various shades of green, and gradually rising in the distance till lost in a long sweep of blue hills, the cattle scattered over the meadows, the trees grouped around the dwellings, and dotting, some here, some there, the entire prospect, form a series of circumstances propitious to the employment of this style. The picturesque results, therefore, more from a collection of many objects than from any single one. It was so understood by the Greeks, who alive to its beauties, arranged their public buildings around squares adorned with trees and statues. These structures differed from one another in size, object, and situation, but were always symmetrical. Here was to be seen one nestling in a grove, there another rising above them all and presenting its pure white in striking contrast with the green foliage around, while still in a different direction several close together, casting shadows from one to the other, charmed the eye with their negligent gracefulness. Long porticoes, also, some devoted to pleasure, some used as markets, gleamed through the trees. All such combinations of art and nature produce those accidental lights and shades characteristic of the picturesque. When the effect of a group of buildings is to be *imitated* in a single one, in order that the imitation may be correct, the various portions of it, as previously stated, should be symmetrical. Whatever the amount and vivacity of the play of light and shade thus obtained in one building, its effect is insipid compared to that of the true picturesque. This requires space to display itself; nature and art exert their powers to create it; a graceful, negligent irregularity, not in its objects, but in their arrangement characterizes it. No hope exists for the picturesque in cities solid with brick and stone.

It will be observed that general principles only have been given respecting the attainment of the various expressions pertaining to buildings. No complete set of rules can be laid down, to arrive in each case at the desired end, for each case demands particular study. Sufficient, however, has been said to conduct this study along the proper path, and even to advance it considerably in this direction.

Architects have discussed for a long time the advent of a new style; a style which is to follow the Grecian and the Gothic. Many have striven for the glory of producing it, but their attempts have resulted in failures. This is what might be expected; for styles were never sought; they rose to satisfy the needs of the times; rough in appearance at first, they became afterwards polished. Without the sublime mythology of the Greeks, the world would never have had the Grecian orders; without the Christian worship, no vaulted aisles would have filled with the swelling notes of the organ; without the Moslem creed, the minaret

would never have been erected to praise the Creator, and call the earth to prayer; without Norman valor, Norman castles would never have frowned from their misty heights, and without luxurious Italy, Palladis would not have designed the architecture which has made his name immortal. It may be asked, then, have we not our needs? Our century, certainly, has not been wanting in activity; and, though boastful, has accomplished some great things. Institutions of learning, of science, and of art, halls and theatres, manufactories and warehouses, railway stations, public buildings, and private residences at all degrees of cost, open an ample field for the exercise of genius. If these constructions be designed to fulfil to the greatest advantage their utilitarian purposes, no regard, meanwhile, being had to decoration, they will then indicate of themselves, to a clear mind, their proper dress. Thus only will we arrive at styles peculiar to our civilization. It was in this way that our predecessors in art obtained their triumphs. Our needs being many, our styles will be numerous. Also, they will be flexible, and apparently variable, yet governed by underlying principles.

But we must guard against the desire to build more cheaply and easily than is warranted by experience. For art depends as much on material and workmanship, as on taste. It is quite lamentable to perceive how far a desire for economy has insinuated itself in all our work. After a structure has been planned as economically as possible, it usually enters into the head of the builder to decorate it, and give it some pretension to taste. Hence, ornaments attached with hooks; hence veneers of stone and of marble. How long can buildings preserve their appearance, built and adorned in this manner? Indeed, what length of time can they last? If executed with the view of transmitting them to posterity, as samples of our skill, what can be the judgment of posterity? The evil would not be so conspicuous, if architects and mechanics would regulate their taste and work by sounder maxims, when employed on a structure of importance. But here also false economy brings with it all manner of deception. The fine is desired, but it is only imitated. The imitation, besides, is the uglier from not being complete, and imperceptible. Sometimes it is placed solely on the front of the building, while the side and back exhibit an honest bareness, and a more ordinary material. The greater cost which is required to carry out the principles of genuine art, no doubt, may check many from attempting it; but by bestowing on essentials that which is so generally spent on foolish ornament, a great amount of the additional cost disappears.

There is another course to pursue; which consists in moderating our aspirations, and contenting ourselves with humbler efforts. Workmanship and material ought to be of equal endurance, so that both may decay together, and not one outstrip the other on the march to ruin. In general, let us have ashlar masonry with real headers and stretchers, like in olden times; with beds and joints dressed deep into the wall, and as carefully for stability as the face for beauty; let the backing be as attentively built as the visible part of the work; let vaulting and massive walls contribute towards rendering our edifices grand and lasting: let the art of stone-cutting be developed among us in all its beautiful branches; let a severe, classic taste preside over our designs; let a building show on all sides the same material, the same attention to please; let a private dwelling look like one, and not aspire to the highest flight of the art—a Grecian temple; let Gothic be Gothic, and not imitated from imitated Gothic; and finally, let us insist upon truth in art as in morals, remembering that a good effort, though of an humble kind, has character and a rank in the scale of art, whereas one which intends to deceive, is passed by unrecognized.

The principles detailed in this paper, are those to which the author has been led in his search after the true. The Grecian and the Gothic, as styles universally admired, have been his guides; while by their light he has seen in others much to laud and much to condemn.

PHILADELPHIA, *Aug.*, 1874.

THE manufacture of a rifled gun weighing 81 tons, was recently begun at the Woolwich Arsenal, England. It will throw a shot of about 1,600 pounds weight, and is intended for the iron-clad Inflexible, which will carry four guns of this kind in its turret. They will be the largest pieces of ordnance in the world.

HEAT AND WATER.

From "The Engineer."

The relations of heat to matter have been carefully investigated by many able men, and from the phenomena exhibited by matter in various forms when heated it has been found possible to deduce certain laws of the last importance in science. But while we admit so much, we are also constrained to confess certain phenomena connected with the relations of heat and matter require an explanation which they have not as yet received, and the reason for this is twofold. In the first place, men competent to the task have not found time to investigate almost isolated phenomena, which from the rarity of their occurrence do not force themselves on our observation; and in the second, from the fact that heat is but a form of energy and not an absolute self-existing entity, complications are introduced into the phenomena to which we refer which permit plausible but unsatisfactory explanations to be assigned for events seemingly so rare that many persons are disposed to doubt that they can occur at all. The relations of heat with that form of matter which we call water, are very peculiar, and it is not perhaps too much to say that they are very far from being fully comprehended; and yet as the engineer has a great deal to do with heat and water in combination, it is extremely desirable that the behavior of the latter under all possible circumstances when submitted to the influence of the former, should be perfectly understood. It would be impossible with the limits at our disposal here to go deeply into this subject. There are, however, one or two points connected with the subject which may be discussed with advantage in our pages. But we must caution our readers that we have no intention of doing more than calling their attention to a few facts, drawing a few deductions from those facts, and leaving to others the task of saying whether the deductions which we suggest in anything rather than a dogmatic spirit, are or are not justifiable.

No one will dispute that in all that concerns the generation of steam, engineers are deeply interested. The process constitutes in itself perhaps the most important application of natural laws to a given end, known in the arts or sciences. How much do we understand about the operation of natural laws in this particular case? Men must have something before them real, tangible, apparent to their senses, on which to hang their faith. In spite of all that has been written and said on the subject, there is a deep-rooted conviction abroad that heat or, as some people still call it, caloric, is a distinct entity. It is so easy to picture to one's self a fluid set free by burning fuel, poured through the boiler plates, and absorbed by the water. Again, water is looked upon as so much extremely fine shot into the interstices in which the caloric finds its way, and forcing them apart little by little, at last overcomes their mutual attraction, and separates them so widely that they become steam. Such a theory is readily grasped. It is, in a word, popular, and it is we know still held by thousands of fairly well-informed men. Others, although they will not put their ideas into the same shape, yet find it almost impossible to get rid of the notion that heat is a material fluid, although they admit that the results of its operation are vibration. Now we know that both theories are wrong; if anything is certain, it is that that vibration of atoms, which is, as we have said, attributed to the influence of heat, is heat itself. "Heat," says Tyndall, "is not matter, but an accident or condition of matter, namely, a motion of its ultimate particles." "The condition of heat," says Rankine, "is a condition of energy—*i. e.*, of capacity to effect changes." Rejecting, therefore, as untenable the idea that heat is a material fluid, we are bound to regard it as a condition or state of matter, and for the accepted and precise definition of this state we are indebted to Rankine and Thomson. We shall not attempt to go deeply into this definition here. It will suffice to say that the fundamental suppositions of this hypothesis are that bodies consist of atoms; that each atom consists of a nucleus surrounded by an elastic atmosphere; and that thermometric heat consists in circulating currents, eddies, or vortices, among the particles of the atomic atmospheres, giving them a tendency to recede from their nuclei and occupy a greater space. From this theorem it has become possible to lay down a definite law of the operation of heat—to determine, in a word, the dynamics of an atom; and

this, be it observed, although at the outset it is as difficult for the mind to conceive the true atom as it is to realize a true point or a true line, according to the Euclid's definition of each. Just, however, as Euclid was able to dispense with an accurate mental comprehension of a point and a line, so is it possible to dispense with the perfect perception of an atom. Instead, we may, nay we must, take something which the mind can grasp; and as the student invariably regards a point in spite of Euclid's definition as a dot, and a line as a fine pen or pencil mark, so in dealing with heat we are justified in identifying the atom with a molecule, and a body of water as so much very small shot, each surrounded by an elastic atmosphere, and these particles and attendant atmospheres continually vibrating or moving among themselves, motion never ceasing until the point of absolute zero, or of no heat manifestation, or about 461 deg. below zero Fah., has been reached —a state of matter, we may add, utterly unknown on this earth. Once we have got thus far, however, we are stopped by an impenetrable wall, beyond which we cannot go. Why the particles should possess motion—in other words, why heat should exist, or why it should be stored up in matter as it is, we can no more explain than the action of gravity. The hypothesis of heat, as we have given it, is good so far as it goes, because it is consistent with known facts. But it must be borne in mind that heat, or strictly speaking, that form of energy known as heat, may produce effects of which we know next to nothing; and that its operation on various bodies is marked by certain anomalies which are not as yet fully accounted for. And this is specially true of water. The first action of heat, for instance, is to cause expansion. The atoms of the body tend to separate and vibrate through larger arcs or ranges. But water expands as it loses heat from a temperature of 39 deg. Fah. downwards. This has been explained by the theory of crystallization. The particles apparently begin to segregate themselves, and to leave open spaces between each group. Why this should be, however, cannot be explained until we know why crystallization takes place—a profound mystery to the entire scientific world at present. The fact exists, nevertheless, and it supplies a somewhat familiar example of the truth that heat may produce, as we have said, effects of the true nature and sequence of which we are in total ignorance. It would be opposed to our experience, for example, to say that by the application of heat we could solidify mercury; but there is not any difficulty in imagining when we have the expansion of water with cold before us, that a fluid might exist which would solidify under the influence of heat. It is essential to the comprehension of the line of argument we are adopting that our readers should realize the fact that heat is but a form of motion; that motion can be changed into heat or heat into force, but that we do not know the precise conditions which determine the conversion of heat into any other given form of energy. Thus, heat, light, and electricity, mechanical work, and magnetism, are all developments of energy. But it would be erroneous to assume that we know precisely when heat will become mechanical work instead of light or electricity. We do generally, and we can predict with tolerable accuracy the conditions determining the form which energy may assume, but nothing more. In a word, we do not know all about heat and its mode of operation, its influence, and its transformations. The world has a great deal to learn on the subject, and nothing can be more fatal to the spirit of investigation than to believe that our knowledge of the laws and phenomena of heat has reached the culminating point, and that Rankine, Joule, Clausius, Thomson, and Tyndall, have told us all that can be told on the subject.

Presuming, then, that we do not yet know all that is to be learned about the relations of heat and matter, let us see whether out of this very ignorance we may not be able to draw some deduction of value. Let us, for example, apply our want of knowledge to the case presented to us by a boiler explosion. We shall be the last to dispute that nine hundred and ninety-nine boiler explosions out of a thousand occur from perfectly well-known causes; but we submit that certain events tend to show that boiler explosions may occur—but we do not say they do occur, be it remarked—from causes which are not understood and from the operation of laws not yet recognized. We have in every boiler, when under steam, an enormous quantity of energy stored up; that energy is practically in the same condition as the powder in a gun—it needs but the touch of the trigger to set it free. The millions of foot-pounds of work stored up

in a large boiler do not operate as work at all, because the motion essential to the performance of external work is not permitted to begin among the particles. The condition is precisely that of a piston of an overloaded engine—reduce the load and the piston moves, and the steam impelling it will give off hundreds of thousands of foot-pounds each minute, although before it was inoperative. Reduce the load on the water in a boiler, and the energy stored up can become motion, work will be done, and once it commences the result is seen in rent iron, shattered buildings, and torn and mangled human beings. There is not a boiler at work to-day that does not contain within its shell a force sufficient to rend it into atoms, and to create destruction around it. Is it then impossible that a condition favorable to the performance of external work may arise within a boiler? Is it certain that the stored up work cannot get permission to begin to manifest itself? Can it be proved that the only manifestation of the influence of heat on water consists in the conversion of portion after portion into steam? Such questions as these must not be dismissed flippantly. It will not do to assert that heat invariably, at all times and at all seasons, converts water into true steam, and does, and can, do nothing else with it. We have in a mass of heated water a condition of matter not remote from that condition of unstable equilibrium which obtains in explosive mixtures of gases or solids. Only a spark is required for the letting loose of the energy stored up in gunpowder or dynamite; and it may yet be found that the equivalent of a spark exists with regard to the stored up energy in water. Indeed, we know, as it is, that an equivalent does in one sense exist. The equivalent is the fracture of the envelope containing heated water under pressure. A moderately large rent in a boiler will cause a reduction of resistance sufficient to establish free motion among the atoms in repulsion, and the destruction of the boiler is complete in a moment. It is possible, indeed, to have an explosion of any violence we please—it is simply a question of opening a sufficiently large rent to set the water free to expand and do work. If the opening is great enough, the water stored within the boiler will, to all intents and purposes, explode; and this, we maintain, is one of the manifestations of heat energy on water which has not been investigated as fully as is desirable. It may be urged that water cannot explode. Any one who has been in a rolling mill working with watered rolls knows the contrary; each time a hot bar goes through, we have a volley of reports as though so many rifles had been discharged. Water quite freed from air may be heated to 312 deg. without boiling, and will then detonate like so much fulminate of mercury. It is difficult to believe that in such a case any true steam is produced; the probability which we would urge on the attention of our readers is that instead of a portion only of the atoms of water flying apart to the distance required to produce true steam, a manifestation of energy takes place simultaneously through the entire mass of water, be it a drop or a ton, and that the result is a very considerable dilation of the entire mass without the production of true steam. That such a dilation is possible has been proved by laboratory experiments, in which the whole of a small quantity of water has been caused to become invisible, although the resulting steam, if so it may be called, did not occupy more than two or three times the space originally filled by the water. If we grant this to be possible in the case of the water in a steam boiler, we admit nothing but that heat can manifest itself as a form of energy in a way not usually met with. It is no more inconsistent with reasonable presumption to suppose that the work stored up in a boiler should suddenly be displayed in the tangible form of dilating the whole mass of water, and driving its particles farther apart, than it is to suppose that the only effect of the operation of a furnace will be to produce steam. It is contrary to experience to suppose that such a dilation can take place, but only to an experience which it may be asserted is limited. It may be pointed out again, that in every case where a boiler bursts with violence the exploding power of water is clearly proved. If it is argued that water cannot explode—by explosion we mean here the disseverance of a body of water into the finest possible spray, a spray of molecules by the natural repulsion of the molecules due to heat—then must the violence of a boiler explosion from any cause, such as corrosion, or over-pressure, or shortness of water, remain utterly without explanation. But we know that the natural cohesion of the molecules is here overcome in an instant; and that water highly heated

does explode like so much gunpowder, and that to cause highly-heated water to explode, it is, for one thing, only necessary to remove the pressure suddenly. From this follows the deduction with which we must conclude this article, namely, that if it be possible for water to explode under one condition, well understood, that it is not impossible it may explode under other conditions not understood, and as a result of strictly natural laws, the operation of which has not yet been recognized.

ARCHITECTURE—ITS SCIENTIFIC AND ESTHETIC ASPECTS.*

From "The Builder."

No one who is at all deeply imbued with a feeling of devotion to his art, and who has had to carry out his views, as best he could, in the rough friction of every-day life, with its many hinderances and discouragements, will undervalue the difficulties which beset those who would speak authoritatively about architecture.

An artist in such a case would know but too well how far his own works have fallen short of his cherished ideal to be inclined to adopt that spirit of fierce denunciation which so often passes now-a-days for a knowledge of art. He would naturally be the severest critic of his own achievements, and would know that to his criticisms a *tu quoque* retort might often be expected. Nevertheless, whatever the difficulties which beset him, the lecturer must remember that in art, as in religion, the message is everything, the messenger nothing; and that in matters appertaining to architecture, more especially, difficulties only exist in order to be conquered.

I can never forget my first experience of the Royal Academy lectures on architecture by Professor Cockerell. With him devotion to his art was a passion, chastened and regulated by the refinement of a scholar, and the thoroughness of a most conscientious artist. Urging, both by precept and example, the importance and exquisite beauty of Greek architecture, he was ever ready to hold out a helping hand to the wayfarer in other paths of art, for to him every artist was a brother.

Since those bygone days there have been many changes in public taste and practice; and it can do no harm to recall to memory a time when much was enforced which is now neglected, and to caution the art student, as Professor Cockerell was fond of doing, against mere "fashion" in architecture.

It might be instructive, and certainly would be interesting, to inquire into the various "fashions" which have prevailed since the days when this warning was first addressed by the Professor to the students of the Royal Academy in Trafalgar-square. Greek art and traditions were then more fully recognized by architects, in practice, than is now the case, and the Gothic revival was in its infancy. Professor Cockerell was led by his natural taste, and also by circumstances, to enter into the spirit of the architects of ancient Greece with all the devotion of an enthusiastic nature, much as was the case with our late distinguished member, Mr. Gibson, with regard to sculpture.

The latter, as we have lately been reminded by Mr. Atkinson, would never tire of maintaining that the Greeks were always right; and his first object, when engaged in composition, was to discover how the Greeks would have dealt with a similar problem.

His architect brother artist had arrived by study and research at a very similar conclusion. Although not slavishly adhering to precedents, his works are so pervaded with the delicacy and finish of Grecian influences, that we can fancy him ever referring to these classic principles as the main test of excellence, and repeating with Gibson, "The Greeks are always right."

He neglected no opportunity of urging, by precept and example, the study of Greek art; and I venture to think that such advice, although it may not for the moment be fashionable, was never more needed than at the present time.

Professor Cockerell had, moreover, an especial claim to attention, as having contributed in no small degree to bring a knowledge of his favorite architecture before his profession and the public. By his discoveries at Ægina and Bassæ he added fresh materials for that appreciation

*Extract from a lecture at the Royal Academy, by Edward M. Barry, R. A.

of Grecian art which led thoughtful artists to consider what must have been the exquisite keenness of perception, mingled with a wondrous refinement in regard to the subtler effects of beauty, which animated those architects of old, who had so perfectly learned to work, hand and hand with the sculptor, each being necessary to the other, and each contributing, to an extent never yet surpassed, to the perfection of the work before them. The enthusiasm which the Elgin and other marbles excited among lovers of art, led naturally to a strong admiration of everything which belonged to Greek architecture, and to a general attempt to introduce its forms and decorations into the buildings of the day. In this work Professor Cockerell had no small share; and though some of his teaching may seem to have been since engulphed in those whirlpools of fashion which he deplored, it is not easy to prove that our art has passed into a more healthy condition by the adoption of different principles, or by the imitation of different models. I must therefore impress upon architectural students the neeessity of studying with more care than is now too often given to them, the principles of Grecian architecture. This is, of course, a very different thing from advising a pedantic reproduction of forms, or an actual copying of examples, which no one would deprecate more strongly than myself. Too much of this has been done already, and no one can desire the repetition of a movement which encumbered our houses and public buildings with useless features, inconsistent with the wants of the nineteenth century, and the exigencies of the English climate. But, while avoiding this snare, can it be useless to draw attention to the refinements which were habitual with the Greeks, although they can scarcely be discovered by our apparently rougher perceptions, without previous study and the practice of critical observation?

The entasis of columns may be referred to as one of most prominent illustrations of my meaning. No one would now dream of designing a classical column without entasis, but this was not always the case; many modern columns have been made with straight sides, and the discovery of the refinement of the entasis was only made by careful study of the best examples.

Mr. Penrose has shown us how many similar delicacies of proportion exist in Grecian work, to reward the student who has eyes to see and taste to appreciate the hidden beauties which lie beneath the surface.

Surely there are lessons here for the art student of all times; and who can say that in these pushing, eager, restless days, there is no room for the still small voice which teaches that breadth, simplicity and refinement of proportion and ornament are the very essence of art, and that they may be seen displayed in the architecture of Greece as they have never been before or since.

While calling to mind my pleasant personal recollections of the days when Professor Cockerell enforced these principles from his chair with so much learning and earnestness, and a charm of manner peculiarly his own, these reflections have pressed upon me the conviction that whatever may be the dominant fashion of the day, an investigation of the principles of beauty in art can never be without advantage, and that in such an inquiry the triumph of Greek architecture must ever hold a prominent place.

I can also the more gratefully dwell upon Professor Cockerell's teaching from a remembrance of the catholicity of his doctrine. Striving by study and careful examination to detect those principles of beauty which must ever be the same, however differently they may be illustrated or emphasiezd in various styles, Professor Cockerell gave no encouragement to an intolerant depreciation of forms which were not those to which he gave his special allegiance. No one could express more heartily and unreservedly his admiration of Mediæval architecture; and some of you may remember the learning and artistic sympathy which he brought to bear on Wells' cathedral and other Gothic masterpieces.

As regards this liberality and breadth of view, it cannot be out of place to point out that if, with our historical knowledge, we are ever to have great artistic achievements in the future, the artist must rise superior to those prejudices which would seek to close whole volumes of past history, and would confine him to a narrow line of study, and still narrower sympathies.

It is now seventeen years since Mr. Cockerell retired from the Professorship of architecture at the Royal Academy, a few years only before his death, in 1863, which left a gap in our profession that has never been exactly filled. It may well be said of

him, that his works live after him, and that he has left enduring claims on our respect and admiration in this place.

In entering upon the object of these lectures it must, I fear, be admitted that the prospect before the architectural student has never been more beset with perplexity than at the present moment, when so many difficult problems are daily pressed upon us for solution.

What form is our art to assume? On what styles of past days is it to be based? Or is it to be altogether new? In what way are modern scientific discoveries to be dealt with? Is an architect to be a sculptor and a painter also, before he can be termed a true artist? These are only a few of the controversies which will readily occur to your minds as now calling for consideration, while over and above them all voices are loudly heard proclaiming that our whole system of architectural practice must be revolutionized, and that success will best be achieved by deposing the architect from his post of supremacy in favor of a commune of workmen.

Many signs of the times point to a disorganization of public taste, leading to an indifference to what is good or bad in architecture; and it daily becomes more necessary to find some resting place on the true principles of art.

If we look around on the state of architecture generally among civilized nations, we must be struck by the fact, that all over the world a period has occurred when its productions have ceased to display the higher artistic qualities formerly inherent in them, as if they had been suddenly paralyzed by some fatal disease. In our own country we can trace the wonderful progress of Mediæval art, from the days of Harold to the time of the Edwards, and thence by a process of decline to its fall, in the Tudor reigns. We have since seen revivals, both of classic and Mediæval types, and of these I must hereafter speak a little in detail. It is certainly difficult to assign the reason why, up to a particular time, it appears to have been natural for men to love and achieve beauty in their works; while, in these later days, ugliness would seem to be the common heritage.

We know that, formerly, every detail of architecture was replete with interest, as if by instinct, so that the very hinges of doors were works of decorative art. This, moreover, was not done, as it might be done now, in exceptional cases, but it was the rule. The men who carried out these works were evidently penetrated with the spirit of their art; and it was as natural to them to work gracefully as it is to the modern workman to create useful ugliness. This difference of spirit dates chiefly from the discovery of printing, and the Reformation, which encouraged freedom of thought, and opened to the intellect of mankind paths till then closed or little frequented.

We cannot suppose that the sum total of human intelligence decreases as years roll on and the world grows older; but may it not be that we shall find the explanation of the apparent decline of the artistic faculties in the diversion of force, occasioned by the devotion of the intellect to other lines of thought and achievement? In past times the want of facile means of communication kept the bodies of men rooted to the spot where they were born, and the absence of intellectual freedom closed to their minds those spheres of usefulness which are now open to all.

Abbeys and cloisters contained recluses, who, in separating themselves from the world, were glad to devote themselves to those artistic pursuits, such as architecture, painting, sculpture, music, illumination, embroidery, and the like, which would add to the splendor of the church and its services, and would be free from any suspicion of heretical free-thinking.

The pursuit of learning has had an opposite effect. It has prevented the intelligence of the world from being concentrated on any one subject, or group of subjects, and it has caused the great mass of the people to care more for philosophy and science than for art.

We are surrounded in this place by the buildings of learned societies, and there are many others scattered about London and the country, while the progress of science adds daily to their numbers. I was astonished to hear lately that for telegraphic engineering, a profession almost of yesterday, there is now an institution numbering upwards of five hundred members.

Before this scientific activity became possible, we may assume that a large portion of the intellectual and constructive powers of mankind which are now given to it was likely to be devoted to some of the various branches of art, which was, in fact, the common language of the educated classes.

We may as well expect to turn back rivers to their sources as to reverse the great tide of modern thought; and all experience of its tendency shows that it flows in the direction of the division of labor. The stream of knowledge is now so great that no man can venture to think he has mastered it all; and even the greatest minds must be contented to follow thoroughly some rivulet of truth, while accepting, on other points, the dicta of fellow-inquirers.

This being so, we cannot expect architecture to be any exception to the general law. It cannot command public interest if it ceases to be the expression of the wants and tastes of men.

Considering, moreover, the tendencies I have alluded to, can it be seriously imagined that the architecture of the future is to be committed to individual workmen, giving no guarantee of harmony, and owing no allegiance to the superior authority of the architect? The whole teaching of experience appears to be opposed to such a proposition, and to prove that the architect of the future should be not only a skilled artist, but also a man of scientific knowledge, and in harmony with the spirit of his time.

While it is true that we should gain by having our buildings expressions of the variety of interest, caused by the devotion of many minds to the details of the work, it is still essential that there should be a guiding spirit, and this must be that of the architect; the true reform of ordinary architectural practice would be to lessen the oppressive burden of petty business cares, which, under our present system, press daily upon him, and tend to deaden his devotion to pure art.

Every age of the world we live in has its own special characteristics, just as is the case with the human unit, and we misunderstand the teaching of history if we suppose that the outward signs of progress must always be alike, and must be the same in kind and degree as those to which men have been accustomed in the past. The architects of old worked, as we have no doubt, in perfect harmony with the spirit of their times, and we must expect to find that their mission and ours differ widely, according to the variation of circumstances and the characteristics of different ages.

In many respects it may perhaps be asked whether architects, in these utilitarian days, do not work under less favorable conditions than their brethren of old. It is difficult, for example, to approach the composition of a great work of art with a mind depressed by insistance on the "lore of nicely-calculated less or more." In private works, of course, financial consideration must always have ruled; but it is not easy to believe that the great public monuments of antiquity were constructed on this disheartening principle.

We can scarcely expect again to have great architectural triumphs, if the question about any important public work is, not—how shall we get a worthy building? but,—how little can it be made to cost? We cannot fancy the architects of Westminster Abbey compelled to cheapen their design by reducing their mouldings, omitting the diapers and carvings, or leaving out the groined roofs, in order to save expense. It would, of course, be easy to blame architects for failure under such circumstances; but would it be fair to do so?

I only put this question hypothetically; for, though we may conceive that such things might happen in Laputa, we must not suppose that they could occur in a country like ours, so rich and so prosperous, that it is the treasure-house of the world,—a country which provides, moreover, museums, picture-galleries, and a Government department of science and art for the cultivation of the public taste.

Great nations, however, sometimes do little things, and their very greatness makes them impervious to criticism. It has been said that no one but a banker could walk down Lombard street in a bad hat; and in a similar way, it is perhaps only rich communities that can afford to show with impunity a public indifference to art. At any rate, in our own case, artists may be allowed to hope that the spirit of utilitarianism, pure and simple, will never be allowed to be the sole guide of public policy in respect of architecture. It will not be creditable to us if history should record that, with pecuniary resources beyond those of any other time or country, we leave as our contribution to architectural art, public works showing, in their mutilated features, only too evident proofs of a parsimonious origin.

From these possible difficulties of the architect, we will now turn to other considerations. We are often told that a new style is the want of the time, though why this should be required more than a new

language, it is difficult to say. We have, however, to decide if novelty is to be our aim in architecture, or if it is to be archæo'ogy. Again, is engineering architecture? and if not, where is the missing link? You will perceive how many sided is the study of our art, and how much it differs in that respect from painting and sculpture. One difference will at once suggest itself, in as much as architecture is a science as well as a fine art.

A painter designs his picture, happily for himself, with no thought of constructional or economical difficulties. The shadows which fall so easily from his brush must be constructed by the architect. The latter must see in his mind the effects which he intends to produce, and must build them up, not on canvas or paper, but gradually and painfully by the hands of others. If the result fall short of his expectation, he has no power of alteration, no facilities for heightening lights, or deepening shadows. He must be an artist in his design, a man of science in its execution. His science, moreover, must be useful, and not merely speculative. Architecture must not only please the senses. She has to justify her very existence by usefulness. Externally, she may indulge in grace of form, limited only by the exigencies of climate, construction, and by durability. Internally, she must accept the necessity of being bound to combine convenience and fitness with beauty. The arts of design and of building must not clash; but their combination should give a sense of propriety and repose. They should, in fact, illustrate the lesson which Mr. Weekes taught us so well a few nights ago with respect to sculpture, that "beauty is utility."

Architecture must then contrive and construct its artistic effects, remembering always that they must grow naturally out of the circumstances of each case, and that the greatest art conceals its modes of operation. Nothing can be worse than the obtrusion of details, obviously not required, except for display, sacrificing the higher qualities of art to a pretentious fussiness.

Without ornament, indeed, architecture as a fine art does not exist. Nevertheless, though ornament may be essential, it must be an integral part of true architecture, not a mere *applique*, like the beauty patches of the court ladies of Lely or Kneller.

It follows, therefore, that architecture must be studied by those who would practice it, both as a decorative art and as a useful science.

If to some architecture may seem to be degraded from the position of a fine art by its utilitarian associations, it must not be forgotten that to this circumstance it owes much of its attractiveness to all sorts of people. It may, therefore, be well briefly to consider this phase of the subject, and to pause for a moment in order to examine the grounds of interest which architecture possesses for various minds.

We shall find that it has many charms for many votaries, and that it may be studied for various reasons, and from different points of view. Thus, for some its interest is mainly archæological or historic; for others, scientific; and for others, purely artistic. Of these, the archæological is, perhaps, the aspect which is most common; for who is there so indifferent as not to care for the greatness of the past, and the proud deeds of ancestors? The sentiment of innate patriotism alone forbids that national monuments of architecture inherited from antiquity, and handed down from age to age, should be allowed to perish; and it is, therefore, natural that we should find that a certain archæological knowledge is prized as a necessary part of the acquirements of educated men. Indeed, some sort of archæological taste may be said to be universal, for even in the most savage tribes, traditions and ancestral "customs," often, as we know, of the most horrible nature, are practiced and venerated simply for their antiquity.

This kind of archæology is, of course, far removed from art; it interests itself in objects of antiquity because of their age, and not because of their beauty or artistic value; it seeks only to satisfy those cravings for a knowledge of the past, which are as much a part of our nature as the yearning to discover the secrets of the future, which has always pervaded every people, nation, and language.

In architecture, archæologists find a fruitful field of inquiry, apart altogether from any search after beauty. Heraldry, for example, one of the most important of archæological studies, is so allied with architecture that it is difficult to study it without, at the same time, learning to appreciate architectural forms, and the various gradual modifications of them, which have been brought about at different dates.

Thus, to mention only a trifling instance, the shape of the shields on tombs will serve to mark the date of the monument; and no archæologist would confound the early twelfth-century shields of the Knights Templars in the Temple Church with those which abound in Henry VII.'s Chapel at Westminster. In the one case there is a long and simple acutely-pointed triangle; in the other, more complex curves, and a width nearly equal to the height. This, of course, is more an archæological than an architectural detail, but it may be referred to as showing the importance to the archæologist of observing architectural forms; and such observation would naturally lead up to the more extended inquiry of the architect into those gradual changes of the shapes of columns, arches, window tracery, and the like, which mark so clearly the step by step advance and decline of Mediæval architecture in this country.

In nothing has our time been more remarkable than in the impetus given to archæological inquiries, and there are now few parts of the country which do not display results of the activity of those who have interested themselves in the architectural remains of past days.

This archæological taste has found its chief vent in the very remarkable revival of Mediæval church architecture which the present century has witnessed, and to which I shall have to return in my next lecture. A movement partly theological, partly archæological, has covered the country with restorations, and new works carried out in the spirit of restorations. The expenditure on our cathedrals and old parish churches has been enormous, and besides this, new Gothic churches, school, and buildings, chiefly ecclesiastical, have arisen as if by magic around us.

This circumstance is the more remarkable, when we contrast with it the comparative apathy on such subjects, of France, and the continent of Europe. It is also noticeable, as having occurred at a time when free thought is pushed to its utmost limits, and when, in most things, men are apt to regard the past with unquestioning reverence.

If we ask, however, how far the revival movement has forwarded the interests of art, the answer is not quite clear, and probably the time is hardly come when a complete answer can be given. A great measure of success has doubtless been obtained from an archæological point of view; but it may be hoped, rather than asserted, that a greater insight has been gained into the true principles of architecture, which may lead it to progressive glories hereafter such as those that have been chronicled in the past. To critical observers, who regard this state of things with impatience, and are ever calling for novelty and revolution, it may however be suggested that a knowledge of the past is the best education for progress in the future, and that after the period of artistic darkness which marked the commencement of the present century, it was inevitable that any earnest revival should assume an archæological complexion. It may be that this powerful force has now spent much of its power; and it is certainly difficult to see how revivalism, pure and simple, can go much further than it has already done; but the question still remains whether our art in the future is to be based on Mediæval principles, to which alone some would bid us look for the secret of success.

If this is to be the case, it follows that no other style should be cultivated. Is this a conclusion that can be accepted, with the evidence around us, of what the revival has done for us? Is it consistent with the development of the sister arts, in all their fulness in connection with architecture? May it not rather be due to an exaggeration of that archæological study of which we have been treating, pushed beyond the point at which it ceased to act as a trustworthy guide? It is the more necessary to guard against the fascinations of a purely archæological view of architecture, from the circumstance that our Mediæval revival has been from the outset very much mixed up with questions of religion and ritual. These matters can of course be only barely alluded to here; but it is necessary for the student to keep them in mind, if he would understand clearly the history of the powerful movement to which reference has been made.

Architecture has in all ages been intimately connected with the religions of mankind, and the great monuments which remain to us are for the most part the result of the devotional feelings of those who erected them. Thus we have the tombs and temples of Egypt and India, the temples of the Greeks, and the cathedrals of the Middle Ages. It was natural, therefore, that any great religious revival should show

itself in our architecture. In addition to this ecclesiastical influence, there has also arisen a keen desire to inquire, more minutely than has hitherto been usual, into daily details of past history, and historians have sought to give us careful pictures of the manners and life of olden times. No one pursuing such researches could neglect architecture, which yields the most valuable result, when studied in connection with the history of people and countries.

It will thus be seen that to archæologists architecture offers a very storehouse of treasures, and that in that great study of mankind which we call history, the architect, the antiquary and the historian work hand in hand.

We have now to consider yet another mode of viewing architecture, distinct from archæology, and having little or no reference to its artistic character.

Architecture being, as has been said, a science as well as a fine art, we cannot afford to neglect the attractions she presents to scientific men. Science being essentially progressive, we might fairly expect architecture, in so far as she leans on science, to be progressive also; and the complete separation of what we call engineering from all sympathy with architecture, is a fact which is rather suggestive than satisfactory.

In seeking to forecast the future prospects of architecture, it is impossible, therefore, to overlook its scientific and mechanical, as distinguished from its archæological and artistic qualities. No one can doubt that in our time these characteristics of our art will be full of interest to many who, in other respects, care little about it. They will dwell upon the fact that architecture is a useful art, and has no *raison d'et re* except her powers to serve the necessities of mankind. To these the science of building offers special attractions. How was it that nations on whom we are apt to look down have carried out works the difficulties of which excite even now our wonder and admiration, in spite of our greater mechanical knowledge?—works, dating, moreover, from what may be termed the infancy of the world? Is our greater mechanical progress only to drive out beauty and enthrone utilitarianism?

The great monuments of Egypt, for example, are sufficient to raise numerous questions of the greatest interest from this point of view—Egypt, whose pyramids, temples, and colossi seem to regard the works of the engineer of to-day, which are now being urged on around them, with the contempt of a mighty unchangeable monarch for an upstart of yesterday. Here indigenous architecture seems to have died out, and Western civilization is represented by the shriek of the locomotive in the silent wastes of the African desert.

Few things, again, can be more interesting and suggestive than to study the influences of climate, race, and habits, on architectural forms, and to notice how construction has given birth to beauty—as, for example, by the introduction of the arch, the use of columns, bold projections to shelter from the rays of the sun, etc. These may all be termed the utilitarianism of our art, and are as interesting to the engineer as to the architect; but you will see how closely they are connected with artistic beauty, and how necessary it is for the architect to accept frankly and thoroughly the conclusion that his art must be accordant with the laws of convenience and common sense.

How far this conclusion may be carried is the problem before him. Make convenience the absolute ruler, and the result is the ugliness and barrenness of modern engineering. Depose it altogether, and our art will become the laughing stock of a world fully alive to all the advantages, though perhaps not a little deaf to the dangers of a highly-wrought and mechanical civilization.

Engineering may almost be said to have discovered the use of iron, as employed for construction in these later times, and in the choice of materials, the architect must, in any case, be influenced by scientific considerations. Materials, moreover, govern design. Assuming that the principles of the design of the Parthenon are based upon traditions of wooden construction, we can see that the modifications of size and form of the various parts which have been adopted in marble, were the necessary consequence of employing a different material. This principle of using fitting materials, and designing accordingly, was never better carried out than by the mediæval architects of our own country.

Thus, in districts where stone was good and abundant, we find groined roofs and elaborate masonry. In places where timber was the best material available, we see the curious timber constructions, and the beautiful open roofs which distinguish the architecture of Cheshire, Lancashire, Worcester-

shire, and some other English counties. The brick architecture of North Germany and Belgium will also readily occur to you as an illustration of this principle, and you will see how our art, in its best days, has always recognized utility. We may be sure it must always preserve this character if it is to retain the respect of mankind.

In the aqueducts of ancient Rome we have a proof that it is not necessary that an engineering work of the most utilitarian character should be tasteless and ugly, and there can be no reason why the architect should not sympathize with the engineer, quite as thoroughly as he has been accustomed to do with the archœologist and historian.

It is, however, the merit of architecture, that while admitting to the fullest extent, the varied interests to which I have referred, it possesses yet another, the greatest and most comprehensive of all, in its artistic character. The mother of art, it welcomes under its roof all that can claim fellowship in that glorious brotherhood. Indeed, architecture cannot be said to discharge its true mission as a fine art in its fullest sense, except in alliance with its two sisters of sculpture and painting.

This consideration can hardly be too emphatically insisted on as regards its bearing on the style of the future, of which we hear so much nowadays. With regard to this combination it must always be remembered that architecture, like music, is a conventional art, while painting and sculpture are imitative arts. Nature must ever be, in a greater or less degree, the teacher and judge of the latter; while architecture can be referred to no rules but its own, and to that subtle sense of beauty and fitness which is implanted in the human breast. It is this instinct, refined and cultivated by art, which forbids that we should be satisfied with the bare provision for our wants supplied by engineering, and makes us desire some grace to be added to the simple necessities of structure. To add this grace without affectation or untruthfulness is the duty of architecture as a fine art, and her work must not only display beautiful detail, but also fine proportions. It is but too common to overlook the absolute necessity of good proportion, and to rely on ornament alone. This dangerous tendency has been, perhaps, somewhat fostered by the greater attention lately given, and rightly given, by students to free-hand drawing. It is a tendency to be carefully watched, as it easily leads to abuses. Nothing can be subtracted with impunity from a perfect work of architecture; but it can better suffer a loss of its ornamental details than an injury to its proportions.

The Greeks were probably the greatest masters of proportion the world has yet seen; but the tendency of our own later time has too often been to ignore this important quality, to the loss of refinement and of true architectural grace. Perfection of proportion does not mean, however, neglect of scale, as is sometimes erroneously supposed. We have all heard it said that St. Peter's at Rome looks smaller than it really is, in consequence of the harmony of proportions; but this is, in my opinion, altogether an erroneous and misleading statement. If St. Peter's does not impress us with its real size, we must seek the reason elsewhere than in its good proportions, for it can be no merit in a great architectural work to efface itself. An architect is not to be thought successful, if the gross result of his employment of great opportunities is only to produce at a vast cost, the impression that would be created by lesser efforts. The real truth about St. Peter's is, not that the proportions reduce the apparent scale, but that the harmonious effect of the proportions is marred by incongruous detail and fewness of parts, all on a gigantic scale. The enormous order and huge figures, and not its beautiful proportions, have to answer for any disappointment with St. Peter's. If the parts of its architecture had been smaller and more numerous, with its general proportions remaining as at present, St. Peter's would have appeared, as it is, one of the largest buildings in the world; and the interior, more particularly would have gained the effects of scale without losing those of proportion which it now possesses.

The student will learn from this example that he must not be satisfied with the sensation of pleasure, or dissatisfaction, which he experiences when face to face with great monuments of architecture; he must inquire the reasons of their success or failure, and seek to define the secret of the harmony or incongruity of their details and proportions.

To those who study architecture in this spirit, beauties will be revealed which are hidden from the mere utilitarian observer, and they will at the same time gain an in-

sight into the difficulties as well as the resources of their art.

Owing to the universal interest which architecture possesses, we find that it can attract the unlearned, probably to a greater extent than the sister arts are able to do.

The grand effects produced by scale alone may often suffice to explain the impression produced on the minds of the multitude, by an art which does not work in aristocratic seclusion, for the benefit of the few, but appeals openly to the many. Of course, it will only be the few who are qualified, by study and knowledge, to speak authoritatively on its inner subtleties, and its broader characteristic must always be those that will interest the uninstructed observer.

To be able to see properly will ever require education, and the power to criticise is not an instinct, although the power of grumbling may be so. There can be little doubt that an art so essentially conventional as architecture can only be fully appreciated by those who have acquired an insight into its principles. Whether in respect of painting, sculpture, or architecture, whatever there may be of instinctive appreciation in individuals, the power of sympathetic criticism can only be gained by knowledge. In fact, in these cases there is room for what may be called the science of art,—science being, after all, only the concentration of the existing accurate knowledge of any given subject. Indeed, even in observing nature itself, men find the advantage of acquiring instruction, although it might have been supposed that enjoyment of her charms would be a thing of course. There cannot, however, be a doubt that this feeling has varied greatly with different races, and even with different generations, of the same race. Those who know Mr. Ruskin's descriptions,—say, for example, his analysis of clouds, trees, and mountains,—will see how much increase of pleasure in the beauties of Nature herself may be gained by a scientific study of her phenomena, which forms, in effect, the art of "how to observe." Knowledge, then is required in the critic as well as in the artist, and where it abounds a genuine criticism is of the highest value.

It points out to the younger aspirants the way of progress, and exhibits the moderation and diffidence which accompanies true knowledge. It is, of course, free from that arrogance and bitterness which has led the present Prime Minister to refer to critics as "those who have failed in literature and art."

I have now touched lightly upon the interest excited by architecture in its threefold aspect,—archæological, scientific, and artistic. The latter quality is that with which we have chiefly to deal in this place, but the others must not be neglected. There can surely be no reason why architectural progress should be regarded as at an end, when we consider the permanent interests which she has in her keeping. Whatever changes the future may bring forth, the art of building must ever be a necessity, and there will always exist tastes, and artistic aspirations, which will refuse to be satisfied with bare engineering. Architecture, then, must ever have charms for all; reserving the greatest enjoyments for those who, having learned to observe properly, can enter into the inner sanctuary. It is not necessary that she should demand an unanimity of taste, which, if possible at this stage of the world's history, would be undesirable; and she is, therefore, able to rely on that universal love of beauty, to which, after all, must be the final appeal of art.

We have seen that there should exist among civilized men an interest in architecture, which while exerting varying degrees of attraction on different orders of minds, would yet lay claim to a catholicity denied to other developments of the artistic faculty. To the archæologist she offers the key by which he can open the stores of knowledge of the past; with the engineer, she will cooperate in working out the destinies of the present; while to the artist, whether painter, sculptor, or architect, she gives a welcome, and displays treasures of exquisite beauty and infinite variety. Moreover, striving onwards for the future, while reverencing the past, she does not hoard her charms in any churlish spirit, but throws open her treasures to all the world. She connects herself naturally with the history of mankind, with the public and private life of nations, with their knowledge and progress. She has ever been the handmaid of religion,—the nursing mother of art.

Such has been architecture in the past. What is it to be in the future? Are its triumphs over? Are we to be content with the copying of barren revivals? Surely this can not be. All sense of artistic beauty has not vanished before the steam-engine. On such of you, gentlemen, as have just entered, or are about to enter, the noble

profession of architecture, these questions will press, and from you will require a solution. If they are to be answered satisfactorily, there must be no half-hearted devotion to your art. Moreover, in these days, far more even than in those of Vitruvius, an architect should not be the mere master-mason, to which some writers would seek to reduce him. No one can afford to lightly estimate the value of general culture, and certainly not the architect, as a member of a responsible, difficult, and learned profession.

Remember the catholicity of art, which forbids bigoted intolerance and opinionated dogmatism. Study carefully for yourselves the remains of ancient masterpieces in our museums, and in the grand old buildings both abroad and at your doors, and avail yourselves fully of the facilities which are offered in this place and elsewhere for free-hand and figure drawing.

As regards science, do not let it be said that architects are behind the age, but qualify yourselves to take your part in it with knowledge, enthusiasm, and integrity.

Great characters lead to grand ideas; noble thoughts produce noble deeds; and if you will bear this in mind, my first professorial lecture will not have been given in vain.

THE EDUCATION OF CIVIL ENGINEERS.

By THOMAS C. CLARKE, C. E.

Transactions of American Society of Civil Engineers.

Men's characters are the resultant of two factors, birth and education—education, used in the broadest sense of the word, and meaning the development of all our faculties, both by instruction or the education of the schools, and by that larger education of the world which comes from experience and practice.

Some men are born with such great natural abilities that they educate themselves in spite of adverse circumstances and become leaders by the sheer force of genius. But such men form the exceptions and not the rule. Most of us are quite as much, if not more, indebted to education for success in life, than to our natural powers, and it is of the education of this class for that profession or art which we call Civil Engineering, which I have to speak.

The methods of this education used in this country and in England differ materially from those on the continent of Europe. Here we begin by a course of study at some school, college, or technological institution, and complete our education by serving as assistants on some class of public works, for which we receive more or less payment. In England, the course is the same, except that there boys begin younger and with less perfect theoretical education; then they serve their time under some practicing engineer from three to five years, and pay him a premium of £300 to £500 for the privilege. This they do, because their chance of future employment depends on being personally known to some engineer in large practice. On the continent of Europe, practical training by serving on public works as an apprentice to some engineer is unknown. Education begins at the other end, by the compulsory acquirement of a high degree of theoretical knowledge. Partly with this and partly afterwards, a certain amount of practical information is given, but the leading idea is to make a man a thorough engineer theoretically before he begins or is even allowed to practice.

In this country, the tendency, of late years has been towards the continental methods. We have attempted with a wise eclecticism, to combine the advantages of both systems, and educate our engineers in the theoretical principles of the science first and then let them acquire practical knowledge by practice itself.

The important question for us to consider, and to which I wish to call your attention to-day, is, whether a classical education should be combined with a purely scientific course or not, in that earlier part of engineering education which is got in the schools. We can answer this question only by considering what is the object of education at all?

It is to enable us to know ourselves and to know the laws of nature. To know ourselves, we must know the capabilities of the human mind, and this will best be found in the literatures of nations. To know the

laws of nature, we must study the physical sciences. The study of letters is the history of the development of human force and will. The study of nature is the study of those forces which lie outside of human will.

It is the office of the engineer to subdue these forces by human will for the benefit of man—or as the motto of the British Institution of Civil Engineering has it, "Civil Engineering is the art of directing the great sources of power in nature for the use and convenience of man." Man and nature, then should be his study. These are the views of Matthew Arnold, who strengthens his own authority by the opinions of other distinguished educators. My own experience coincides with this; observation has shown me by numerous instances, that those persons who have come to the study of Civil Engineering after a thorough training in both natural science and also, to use the good old expression, "the humanities," are those who make the most rapid progress. When a man has learned how to learn, he can quickly learn anything.

The limits of this paper will not allow me to point out in detail the course of studies which should, in my opinion, be pursued. But I may say generally—it is of the greatest importance that what Bacon calls "the relative values of knowledges" be understood, and not too much time be given to one class to the exclusion of others. The mistake of classical teachers is, that they value grammar higher than literature itself. On the other hand, the mistake of teachers of science is, that the mathematics preliminary to a knowledge of the laws of nature, is valued higher than the knowledge itself.

Much time is wasted in our colleges and technological schools over the higher mathematics. Every engineer here will agree with me that the cases where the use of the higher calculus is indispensable are so few in our practice, that its study is not worth the time expended upon it, and we have the highest authority for saying that unless its use is constantly kept up, we become too rusty to use it at all. Unless the student possesses an extraordinary genius for mathematics, I would limit its study to the ordinary analysis.

The time saved I would devote to the study of natural science in some of its branches. What is it? It consists of observations of facts and the relation of phenomena, of drawing conclusions from the data thus acquired and of finally verifying these conclusions by observation and experiment. This is the best mental discipline, for it strengthens both the observation and the judgment. It teaches patience, accuracy and a love of truth for its own sake. I see no reason why the study of the properties of all materials of construction should not be made a branch of natural science, and studied, not alone by taking for granted what the books say, but by observation and actual experiment.

The curriculum should include the study of both ancient and modern languages; the object being to read and understand what is written in them and not to be a philologist. But let it not be forgotten that the study of our own noble language is worth that of all the rest put together. Indeed it is not sure but that the greatest advantage that we derive from the study of other languages is, that it enables us better to understand and appreciate our own. In regard to style and expression, any man who can think clearly, can write clearly. The best style is that which conveys my thoughts to your minds by the line of least resistance.

Let us now suppose that our student has finished his college course. Instead of entering the technological school, I think he should at once go into the field and the office, and learn the actual practice of his profession. His training will have given him the power of generalizing and he will be able to see the principles which underlie all classes of practice, and to distinguish what is most necessary to be learned. He will very quickly find out the reason why things are done. After some time spent in this way in getting experience of how the affairs of the world are really carried on, not how they are said in books to be done, he may, if he can spare the time, go back to the technological school. His practice will have shown him his own weak points and the "relative values of knowledges" taught there, and he will lose no time, but apply his whole force to that which he most needs.

The practice of Civil Engineering is now so much specialized, that by this time he will probably have selected the branch that he means to follow. That branch is the one that he should study in the technological school. Then comes the time, when the

value of knowing one thing well, will be appreciated

If his abilities have obtained for him valuable employment or connections which he is unwilling to break up by going out of business and back to school, he can pursue the special branch of technical knowledge he requires, either by himself or with the aid of a private tutor. If, for example, he takes up one of the branches of hydraulic engineering, let him concentrate his mind upon the science pertaining to it. If he prefers iron bridges as his specialty, he can find occupation for all his powers in studying the application of statical laws to this class of structures.

By this means, whatever he tries to learn he will probably learn thoroughly and well. On the other hand, if he attempts to cover the whole field of applied science, he will have a smattering of many things and have nothing well.

To recapitulate—let the earlier studies tend toward developing the mind of the student, strengthening his powers of observation and judgment, and teaching him to generalize. Then let him go into the field and study actual practice, select his special branch, and acquire the technical scientific knowledge necessary to the practice of that branch. Let him learn general principles in the schools and technical knowledge while in practice.

But a few days ago the greatest of American railway managers and engineers passed away from among us. The life of John Edgar Thomson teaches us some things which it is well to consider.

1. It teaches us first the value of concentration. He gave his whole mind and heart and soul to his business. As has been well said: "It was his birthright, his education, his pride, profit, and amusement," and well did it repay him for his pains.

2. It teaches us the value of training. The method and discipline of his early engineering studies and practice were of the greatest value to him when conducting the larger operations of his mature life. His knowledge of the value of that training has been shown by the kind of men whom he has left as his successors.

3. We see that no man can hold the position that Mr. Thomson did without a very broad and general grasp of intellect. He may be a specialist and know some branch of his profession much more thoroughly than the rest; he must have much special knowledge of the details of all its branches; but all this will avail him nothing unless he has the power of generalizing, which enables him to look at his business as a whole and appreciate the relative values of all its different parts. And this power is naturally given to but few men, but in all it can be vastly increased and developed by the power of education.

I will conclude this paper by recommending the young engineer to take for his motto those noble words of Prof. Clerk Maxwell: "Accuracy in measurement—truth in statement—and justice in action; our noblest attributes as men, because they are the essential constituents of the image of Him, who, in the beginning, created not only the heavens and the earth, but the materials of which heaven and earth are made."

REPORTS OF ENGINEERS' SOCIETIES.

American Society of Civil Engineers.—The Society issue this month the following circular:

At the last Annual Convention, on motion of Mr. J. Dutton Steele, it was—

"Resolved, that a committee of three be appointed to inquire into the various systems of signals in use on the several railways of the United States, and to report upon the same to the next Annual Convention, with such recommendations as may seem important."

Messrs. J. Dutton Steele of Pottstown, Pa., O. Chanute of New York, and Charles H. Fisher of Albany, N. Y., were appointed such committee.

The question of signals has, for quite a number of years past, occupied the attention of railway engineers and managers. In 1866 a very interesting report on this subject was made by Mr. Ashbel Welch, to a railroad convention at the St. Nicholas Hotel, New York. In 1871 a code of signals, rules and regulations for operating railroads, was jointly agreed to by a committee of railroad officers, and the Board of Railroad Commissioners of Massachusetts, which was subsequently adopted in 1872 by the Western and Southern Railway Association, now the Railway Association of America.

Notwithstanding these efforts, there is yet such diversity of practice upon the railways of the United States and Canada, as to produce considerable confusion and to lead sometimes to deplorable accidents.

The employés of the various railway lines come into such close relations at junctions and crossings, and so frequently change their service from one line to another, that it seems important the utmost uniformity possible should prevail in all matters pertaining to the signals and movements of trains.

The committee, therefore, proposes to collect all information on the various systems of signals now in use upon the railways of this country, and to

co-operate, so far as it can, in promoting uniformity of practice in this respect.

Will you be kind enough to send us a copy of your rules and regulations concerning signals, whether embodied in your time-table or book of instructions, together with a detailed statement of such signals as you may wish to call particular attention to, under any of the following heads.

General, or train signals with the steam whistle, the engine bell, the train rope, the hand lamp, the arm and hand, flags, torpedoes, fusees or fire tubes.

S gnal systems by towers, scimaphores or vanes, automatic telegraph.

Special or fixed signals at junctions of railways, grade crossings, switches, stations, tunnels, drawbridges, inclined planes, switch backs.

You will much oblige us if you will send an explanatory sketch of such of these as may require it, drawn in black lines on a scale suitable for publication in the Transactions of the Society.

The committee will feel especially obliged in receiving a description of any system of block signals, either mechanical or telegraphic, which may be in use, or favored by you, together with an account of its workings and of the advantages expected, as well as of any interlocking gear and signals to regulate the entrance and departure of trains at any large station.

It is also desired to know what system of signals would be most applicable to a triple or quadruple track railway, in which certain tracks would be used exclusively in one direction.

Please direct replies to the Chairman, Mr. J. Dutton Steele, Pottstown, Pa.

Respectfully, J. Dutton Steele, O. Chanute, Charles H. Fisher, committee.

IRON AND STEEL NOTES.

The Iron Ore of Labrador.—About eight years ago it was discovered that there existed on the north coast of Labrador, large quantities of magnetic iron ore in sand, but for a long time no one could be induced to seriously take in hand the working of the mineral wealth, whose existence was undoubted. It seems, however, that the time has come at last when those who, for eight years past, have vainly endeavored to find a market for this magnetic ore, which lies in such abundance on the north coast, will see their efforts crowned with success. This species of sand has been known for several years, but to Mr. Lamothe, of Montreal, who accompanied the Southern raiders in their flight, is due the honor of having contributed to their working and development. A company was formed, and forges were built at Moisie. These works have been in operation ever since. A short time was sufficient to show that magnetic sand was to be found not only at Moisie, but almost all along the north shore. The richest deposits are, however, at Matashquan, Kegashka, St. John River, Moisie, and St. Marguerite. Other deposits are also found elsewhere, but not of such considerable importance. Several experiments have been made to purify this sand in a rapid and economical manner, and to make steel by the direct process. Both these problems have been solved. The secret of purifying we owe to Prof. Larne, of the Laval University, and the other we owe to Mr. Labreche Kiger (now deceased) of Montreal.

Two young gentlemen from Quebec, placing great hopes in this new industry, have induced some English manufacturers at Swansea to buy this black sand when prepared. They began in June to put up the necessary houses at a place called Black Point, between St. John's River and Mingau, and twenty-three men have ever since been constantly employed in preparing the sand, which contains in the rough state 30 per cent., and when prepared 99 per cent. of magnetic iron ore. These men prepared ten tons of it per day last summer, but arrangements are being made by which thirty tons per day can be prepared.

The experiments already tried for the fabrication of steel, and the quality produced, give sufficient security to rely on the success of this undertaking. Quebec has established a factory for the fabrication of steel from this sand, and Messrs. Duval and Michaud have already sent up several tons of the ore to that city. At Matashquan, also an establishment is being put up. The richness of the ore discovered in Labrador excels the similar deposit at Taranaki in New Zealand; and there is every indication that the industry thus developed will rapidly extend and become an important item in the commerce of the province.

Compound Cupola Furnaces.—A cupola furnace has lately been patented by Mr. Swain, of Manchester, in which an auxiliary reservoir is attached to the bottom of the cupola. The metal as it liquefies, instead of lying in the hearth of the cupola below the tuyeres, is, in this arrangement, tapped off and collected by a passage in an auxiliary chamber or hearth. The advantages of this arrangement are numerous. This reservoir, which can with ease be applied to any old cupola, enables a much larger quantity of metal, compared with the size of the cupola, to be stored up and kept hot, than can be done with the old style of furnace. It gives an easy method by means of which the capacity of any existing cupola may be readily increased to meet a demand for heavier castings. It is also noticeable that the part of the blast producing heat to keep the charge liquid, is not obliged, as in ordinary cases, to pass through the whole of the fuel. Thus a considerable economy is claimed to be effected. The fuel used being simply that required to effect fusion, the fusion being afterwards kept up apart simply by the hot blast, and the oxidation taking place in the bath itself. The advantages that the inventor claims are as follows: (1) the fusion takes place more rapidly, and the weight tapped is much greater than under the old system; (2) the passage of the hot blast over the surface of the liquid metal, facilitates the oxidation of all impurities contained in the metal; (3) the liquid metal is heated more strongly, and is better mixed; (4) there is economy of time; (5) large masses can be cast with the same ease as small ones; (6) a considerable economy of fuel is effected; (7) the liquid metal can be retained, and be kept hot for a considerable time, in fact, the action of the reservoir has all the effect of refining, the silicon, sulphur, and phosphorus being largely carried off in the bath. The same cupola and reservoir may also be applied for the fusion of pig iron for puddling. The

liquid metal will run then directly from the reservoir to the puddling furnace, and thus save the reheating. This would represent a large economy over the ordinary methods. Another advantage is obtained in the reduction of the expenses in repairs to the puddling furnaces, caused by the reduction of the pig iron on the hearths of those furnaces, since if the metal is introduced in a liquid condition into the furnaces, the production of iron is doubled in a given time, the expenses of repairs and interest on capital are all halved.

RAILWAY NOTES.

AUSTRALIAN RAILWAYS.—The demand for our railway iron in the Australian colonies has been highly encouraging this year. Month by month this demand has grown larger and larger. In August it amounted to 10,031 tons, against 2,295 tons in August, 1873, and 1,993 tons in August, 1872; while in the eight months ending August 31st, this year, it amounted to 55,252 tons against 13,304 tons in the corresponding period of 1873, and 14,577 tons in the corresponding period of 1872. There seems little reason to suppose that the Australians will for many years to come be able to provide for their own rail consumption; and as the activity prevailing in the development of Australian railways is very marked and decided, we shall, in all likelihood, make liberal rail deliveries to Australia for, at any rate, the next five years.

The latest intelligence to hand from the Australian colonies shows that the locomotive is gradually extending its operations in those interesting dependencies. As regards Victoria, it may be observed that the line from Castlemaine to Maryborough, and the first section of the Ballarat and Maryborough line, from Ballarat to Creswick, were opened for traffic on July 7. The Castlemaine and Maryborough line was commenced in September, 1872, and was one of the light lines authorized by the Victorian Railway Construction Act, 1871. The length of the line is 34 miles. The line from Maryborough to Dunolly is in a forward state, and it will be finished in about two months. The construction of the Ballarat and Maryborough line is also being proceeded with as rapidly as possible; the first section, from Ballarat to Creswick, which has been opened for traffic, comprises a distance of 11¾ miles; the second section of this line, from Creswick to Clunes, a distance of 10¾ miles, will be completed in about four months, and it is anticipated that the line will be finished through to Maryborough in February or March, 1875. As regards Tasmania, the Tasmanian Main Line Railway is being pushed through with great energy, and it has absorbed a very large quantity of rails and accessories. Even now this demand can scarcely be regarded as exhausted. In New South Wales and Queensland we find a great deal of railway activity, and in New Zealand several lines of some importance are also on hand.—*Lond. Mining Journal.*

ENGINEERING STRUCTURES.

THE CHANNEL TUNNEL.—The preliminary steps towards the execution of this stupendous project are being steadily advanced, although the undertaking itself has dropped from the view of the general public. The mechanical and geological questions involved were fully discussed in a paper read before the Society of Arts in March last, fully reported in our columns at the time. They have been considered with much care by the advisers of the committee of promoters, Sir John Hawkshaw and Mr. Brunlees. The grey chalk—a mass of strata 500 ft. thick and impervious to water—which forms the principal mass of the cliff at both Dover and Calais, strikes across the channel with so little divergence from horizontally that a tunnel could be pierced within the vertical bounds of its thickness. To ascertain with exactitude the configuration of its outcrop, and the surface outlines of the other associated cretaceous rock,—numerous soundings and borings of the sea-bed have been made in a most ingenious manner by means of an iron tube, over which a hollow shot, fitting loosely, is raised and let fall upon a flange attached to the tube, the end of which is in this way driven into the substance of the sea-bottom, the core thus obtained giving the required sample of the rock perforated. Some hundreds of these borings have been made, and a geological chart of the Channel constructed from these data. These accurate details of the strata and their outcrops have enabled the most promising line of route to be selected, and which is accidentally very nearly that of the Dover and Calais Submarine Telegraph Cable. The plan and construction of the proposed tunnel has received the joint approval of M. Duroich, M. Bergeron, M. Lavallay, and other associated engineers of eminence. The line of the main tunnel, which is to be large enough for a double line of railway, is drawn straight from St. Margaret's Bay, South Foreland, to a point very nearly midway between Calais and Sangatte.

In longitudinal section the proposed tunnel presents a slight fall of 1 in 2640 from the centre towards either extremity, and the vertical depth of the highest point of its floor is 436 ft. from Trinity high-water mark, and 200 ft. beneath the sea-bottom itself. From the land levels of the existing railways the two approaches make long descents of over four miles, each with gradients of one in eighty, into the tunnel ends, over two miles being under the sea, the total of the whole amount of tunnelling amounting to thirty miles. The greatest depth of water over the sea-bed above the tunnel is stated to be 180 ft. Below the railway approaches, and continuous with the floor of the submarine tunnel itself, there will be at each end a driftway leading to vertical shafts ashore for drainage and ventilation. These terminal shafts and driftings are the preliminary works which it is intended to make as tests for the practicability of the general undertaking, and of which, when completed, they will form essential portions. The shafts will be 19 ft. in diameter, built around with 24 in. of brick laid in cement, and the headings, which will be driven by machine—probably Brunton's—will be lined with 14 in. of brickwork, and have internal diameters of 7 ft. Their form will be horseshoe, with straight sides, and a flat inverted arch below the floor. The estimate for the entire preliminary works—which, to satisfy the *amour propre* of both nations, will be carried on simultaneously in both countries—is, with all expenses contingent on their execution, something less than £160,000, including the two pumping

engines, of 2,000 horse-power each. The total cost of the whole tunnel and its accessories is, for the present, put at £10,000,000; but there are those among the engineers who think the preliminary works will afford data for a much lower estimate.

Considerable progress has also been made in the commercial arrangements. The actual position of affairs at this time is that the *projet de loi* has been prepared, and will be presented on the reassembling of the French Chamber in November by M. Caillaux, now minister of Public Works, formerly a member of the Channel Tunnel Committee —the aspect of this Channel Tunnel scheme having thus changed from adverse under the Government of M. Thiers to conditions not unfavorable under that of Marshal MacMahon. Nothing further can be done until then to advance matters beyond their present position, and of course nothing more substantial is likely to be ever effected until a concession be obtained. The promoters, knowing the cost of the tunnel railway will be ten times that of an ordinary one, not unreasonably seek power to levy fares to say five times the French rates, or a maximum toll of about 5d. per mile—the present steamboat rates being 4d., and the English legal first-class fare 3d. per mile. It does not follow, however, that the maximum fares conceded would be the ordinary fares charged. The Channel Tunnel project is to be carried out by a French and an English company, the general management to be vested in a committee whose members will be furnished by the two directorates. Towards the preliminary engineering works each company is to contribute £80,000, of which £40,000 is definitely promised by the Northern of France; and £20,000 more is added by Rothschild Brothers, of Paris, whose intimate relations with that railway are well known. The residue will be contributed by the French members of the promoting committee. With the English company no advance has been made over the original £30,000 subscribed in 1872; but its moiety of the preliminary total it is expected will also be subscribed privately.—*Iron.*

THE WATER SUPPLY OF PARIS.—A correspondent of the *Leeds Mercury* gives the following description of the great works at the Reservoirs of Montsouris: Until these works were completed, the Parisians possessed only 338,000 cubic metres of water, or 1,108,900 cubic feet; that is to say, 140 litres per head. This water comes from the springs of Belleville and the Près St. Gervais, the artesian wells of Grenelle and Passy, the springs south of the city, formerly called "Royal Springs," passing by the aqueducts of Arcueil, the rivers Ourcq, Marne, Seine, and lastly the Dhuis, which is diverted from its course almost at its source, and which made its first entrance into the city of Paris in 1865. The waters of the Dhuis are received in the magnificent reservoirs of Menilmontant on the second story, and comprise 100,000 cubic metres of water, while the first story of these same reservoirs receives the waters of the Marne. It is simply two lakes one above the other. Maxime du Camp justly calls this "a unique construction," for, says he, "when I call to mind the cistern at Constantinople, with its thousand and one pillars, the dam in the Valley of Belgrade, the 'Piscina Mirabile' at Naples, Solomon's wells at Ray el Din, and the cistern of Hezekiah, at Jerusalem, I can find nothing at all analogous, and I believe that in all ages nothing equal to it has been produced. It appears all but miraculous, when we consider its marvellous conception, and the immense difficulties in its construction. It is a triumph of genius and scientific industry." The work has cost 8,700,000 francs, and covers a surface of two acres, and is one-third less in size than that which is now being completed on the heights of Montsouris. In a short time the Parisians will be in possession of an additional supply of water, amounting to 328,100 cubic feet, consequently giving in all 210 litres per head, instead of 140.

We are far indeed removed from the time when François I. had to petition his good city of Paris for a small supply of water, to use the expression of the period, "no larger than a vetch seed," for the use of the Bishop of Castres. In those days 460 cubic metres, or 1,509 cubic feet of water, was the supply for the whole population of the city, and this was in 1669, only two centuries ago. The last of these admirable results was effected by the construction of new reservoirs on the site of the ancient park of Montsouris, for many years the rendezvous of beggars, miscreants, etc. These will be dislodged, another beneficial result of this undertaking.

The great hydraulic works of which I am speaking distribute in Paris the waters of the river Vanne, taken at their source in the Department of the Aube, about 104 miles from Paris, and brought by aqueducts through a pipe of cast iron of upwards of a metre in diameter. This gives 1 metre 10 centimetres cube of water per second, which flows into the reservoirs. These reservoirs are four in number, two on the lower and two on the upper story. They are completely separate, but can be united to each other according to the requirements of the service, or for repairs, etc. It is a perfect forest of pillars made visible by a very peculiar light let in through semicircular air-holes. The shadows cast by the high and narrow arches, in which the water rises upwards of five metres, cause a strange and mysterious appearance which it is difficult to describe, or if once seen to forget. In each section there are 900 columns ranged in thirty equal divisions, making in all 3,600. These columns, as well as the arches and the floor, are made of stone, covered with cement. The columns gradually diminish in circumference until they reach the height of 5 metres 80 centimetres, where the arches commence which unite them. The greatest elevation is 7 metres 10 centimetres. The pillars of the upper story are inferior in height and strength, not being required to support an equal weight of water. This floor will contain only 100,000 metres of water, while the lower floor will contain 200,000 metres. The whole will be covered with 50 centimetres of earth, to be sown with grass, intended to preserve the water from the influence of atmospheric changes. Its external appearance is that of a massive building with but few apertures, and is by no means ornamental. This water will supply the principal quarters of Paris, and will replace that of the river Ourcq, which is in such a filthy condition that the iron gratings through which it passes require to be cleansed three times a day, and during the period of the hay harvest these gratings have to be changed every half-hour to prevent their being broken. This colossal work will cost five million francs—an immense

sum it is true; but will not the benefit also be immense in securing to the population of Paris an almost unlimited supply of pure water?

ORDNANCE AND NAVAL.

TORPEDO EXPERIMENTS.—The third of the series of what are known as the "Oberon Experiments" has taken place. The Oberon was formerly a wooden paddle-steamer, but her bottom has been plated, in order that it may resemble the bottom of the Devastation; and the object of these experiments is to ascertain at what distance from an ironclad a torpedo may be fired without injury to her. At the first experiment, a mine containing 500 lbs. of compressed Waltham Abbey guncotton, saturated with fresh water, was sunk at a depth of 47 ft., and at a horizontal distance of 100 ft. from the starboard beam of the Oberon, which was moored off Fort Monkton. The mine was fired from the fort by electricity, but the ship sustained little or no injury. At the second experiment the distance of the torpedo from the vessel was reduced to 80 ft., but again the ship escaped. The last experiment was under precisely similar conditions, except that the distance was still further reduced to 60 feet. The boats having got clear of the ship, at ten minutes to four the mine was fired. The explosion was followed by a huge column of water being thrown some hundreds of feet into the air, and by much slaughter of fish. On the ship being boarded, a joint of the inlet pipe leading to the condenser from the sea, was found to have been started, and to be leaking, everything movable on board had been displaced, and had she been fully rigged it is probable the upper part of the ship would have been a good deal injured. But, so far as can at present be ascertained, her hull had once more entirely escaped. Some sheep and rabbits left on board seemed none the worse for the explosion. The Oberon w s soon afterwards towed into harbor and docked. On Monday last week she was officially surveyed. The survey resulted in the official conclusion that no damage was inflicted upon the double bottom or the hull of the vessel by the experimental explosion of a sunken mine within a horizontal distance of 60 ft. The slight damage to the joint of the inlet-pipe to the condenser is considered to be solely due to the fact that the condenser is not fastened to the Oberon's bottom in any way, and not at all likely to happen to a condenser fixed in the ordinary way on board all ships fitted for service in commission. At the next experiment, the mine will be placed at only 40 ft. from the ship.—*Iron.*

THE NAVIES OF EUROPE.—The German correspondent of the *Times*, in an interesting article on Prussian ironclads, gives the following comparative list of the vessels of the European navies: —All Europe at this moment has 142 ironclads fit to be placed in line of battle. Of these England owns 38, France 28, Austria, Russia, Italy and Turkey 15 each, Germany 8, Spain 7, Denmark 3, Greece 2. The tonnage of the German ships and the size of their guns are, however, so uncommonly great that, although few in number, they are supposed to be a match for any navy, those of England, Russia and France excepted. Besides these there are 103 iron-cased vessel to be found in Europe for the defense of coasts. Of this number Germany has two; Spain, Norway and Denmark, 3 each; Turkey, 5; Sweden, 9; Russia, 13; Holland, 18; England, 23; and France 30; 431 screw frigates and corvettes make up the wooden array of European strength at sea. Here, again, England, with 132 vessels, 5,670 guns and 50,700 horse power, has the first place. France, the second on the list, records only 52; Russia, 48; Turkey, 44; Spain, 37; Holland 25; Italy, 24; Germany, 17; Denmark, 16; Austria, 14; Portugal 8; Sweden, 6; Norway, 5; Greece, 2. Smaller craft, such as avisos, gunboats etc., of which England alone has 276, with 309 guns, and 13.284 horse power, are not reckoned in this calculation. If England were to man her navy for war, she would require 68,000 men, of whom 22,000 would have to be enlisted for the purpose. Russia for the like object, wants 36,000; France, 33,570; Turkey, 21,000; Spain, 14,000; Germany, 13,000; (every one kept in readiness); Austria, 11,530; Italy, 11,200; Holland, 6,260; Denmark, 4,800; Norway, 3,500; Portugal, 3,300; Sweden, about 3,000. Comparing the total of the German crews with those of the other States, we find it exceeded by England, Russia, France, Turkey and Spain. Spain does not count, so much of her forces existing only on paper; nor can Turkey's numbers be relied upon, she being to a great extent dependent on foreign help for the effective manning and officering of her ships. Hence the German navy is in reality inferior only to the British, Russian and French; and even this statement requires to be qualified, German vessels being much more sparingly manned than either the Russian or the French, and 13,000 German sailors being accordingly not so very much below the strength of 36,000 Russians or 33,570 Frenchmen, as the figures would seem to indicate.

BOOK NOTICES.

ELEMENTARY HISTORY OF ART. An Introduction to Ancient and Modern Architecture, Sculpture, Painting, and Music. By N. D'ANVERS. With a Preface by T. Roger Smith, F.R.I.B.A. Price, $4.00. For sale by Van Nostrand.

It is not an easy task to compress the history of Art within the compass of an ordinary-sized volume without allowing much of what is the essence of such a history to escape in the process. The subject is so large, and requires so much space for its treatment, that when a confined limit is fixed, there is a risk that the result will be little more than a catalogue of names. On the other hand, as painting, sculpture, and architecture are related, it is of advantage for any one about to undertake the study of either to be able to obtain a more or less comprehensive glance at the three. There is no doubt that an elementary history of art has been required, and this Mr. D'Anvers has now given to the public in a compact volume. He has used a popular German treatise as a basis, but has taken care to meet the special requirements of English readers. English art is treated specially, and throughout

he refers to the examples of the work of other countries which are found in the British Museum, the National Gallery, and the South Kensington Museum, and especially among the fine collection of copies of sculpture at the Crystal Palace, and by so doing shows what opportunities are available to those who cannot visit Continental galleries. There are one hundred and twenty excellent German woodcuts in the book—but nearly all are from foreign examples; there are some illustrations among them of English buildings; but there is not one from an English painting or statue. This deficiency might have been supplied without much expense, and the illustrations would then bear a better proportion to the letter-press in the attention given to English art. Unlike certain other writers, the author has no theory of his own to offer as the key to the history of art, and the student cannot therefore be biassed in a way as likely to be injurious as helpful. Although Mr. D'Anvers' book is mainly intended for those who are about to commence the study of art, yet, from its correctness and conciseness, it will be found to be a handy compendium of art history for those who have experience. For general readers, or the great body of amateurs, it will be found most valuable, while the style in which the volume has been produced, renders it particularly adapted for a present or for a prize in schools.—*Architect.*

First Lessons in Theoretical Mechanics. By the Rev. John F. Twisden, M. A. London. 1874. Price, $4.25. For sale by Van Nostrand.

Professor Twisden's treatise on mechanics is remarkably clear in arrangement and style. There are also a very large number of examples introduced as illustrations of principles, and which no less become tests of a student's progress. Only a limited knowledge of mathematics is needed in order to follow the author's treatment of the subject. The book may be recommended as an elementary treatise which is both simple and precise.

Workshop Receipts for the Use of Manufacturers, Mechanics, and Scientific Amateurs. By Ernest Spon. 1873. Price, $2.00. For sale by Van Nostrand.

This volume, which has been published for several months, has merited an earlier notice at our hands as a really remarkable compilation of receipts of almost every kind that may prove of service to those to whom its title page is addressed. But small attempts even at broad classification have been attempted, so that we find the contents of the book somewhat as follows: receipts for mechanical draughtsmen, followed by others referring to metals, cements, dyeing, glass, porcelain, and pottery, varnishes, pigments, painting, masonry, plastering, engraving, firework making, electro-metallurgy, photography, soap and candle making, veneering, marble working, etc. Still by the help of the really very fair index the book possesses, any particular receipt can be selected from the heterogeneous mass, and we must say, in all justice to the author, that when found, the receipts are almost invariably useful, and bear evidence of having been carefully prepared, and submitted to practical criticism before publication. We should imagine, indeed, that the writer must have consulted a great number of authorities, apart from book research, for a large number of the receipts are new, that is to say, they have not been published before, and old ones have been modified, and their usefulness increased.

To add to the value and clearness of the letter-press, a considerable number of small engravings are scattered among the text, and save much space in explanation. We trust that this book has already met with what it deserves—a full meed of success among those for whose benefit it was prepared.—*Engineering.*

Iron and Steel. By Charles Hoare. A Work for the Forge, Foundry, Factory and Office. Charles Hoare, Southampton.

The book before us gives a very useful collection of notes and tables, and which we can cordially recommend to those engaged in considering the details of all kinds of iron and steel work. The author in his preface supplies an excellent guarantee that his book has been compiled with care and accuracy, and that it is generally useful, when he gives a list of all the leading shipbuilding and engineering firms in the kingdom who have certified their approval of it. And we may further state in its favor that this little work has already passed through six editions, a fact which shows that its utility has been pretty extensively recognized. Many useful hints and rules are given for lessening the amount of arithmetical labor, which is always more or less necessary in arranging iron and steel work of all kinds, and a great quantity of useful tables for preparing estimates of weights, dimensions, strengths of structures, costs of work, etc., will be found in Mr. Hoare's book. The following passage we quote from the author's preface, and the statement he makes in this quotation we can fully indorse, after having carefully examined the data he gives:

"Differing materially, as it does with few exceptions, in the treatment of the various processes, it also contains a greater amount of special information on iron and steel working than can be found in any other book. In this department it has found a province of its own, without trenching on ground so ably filled by Molesworth, Templeton, and other established favorites."

A Treatise on the Principles and Applications of Analytic Geometry, By Henry T. Eddy, C. E. Ph., D. For sale by Van Nostrand.

We find in Prof. Eddy's new work some features which we have long regarded as important, but which have hitherto been wanting in an American text book suited to Academic and Collegiate students. Among these are, the improved notation of angles, such as is employed by European writers on modern Geometry—A thorough exposition of the general principles of the science set forth in a series of propositions, and Newton's method of discussion of curves and their singularities.

A great number of examples are afforded for

practice, and in addition to these frequent so-called exercises are given for the more advanced student.

The typography of the book is excellent.

BUILDING CONSTRUCTIONS; SHOWING THE EMPLOYMENT OF BRICK, STONE AND SLATE IN THE PRACTICAL CONSTRUCTION OF BUILDINGS. By R. SCOTT BURN. 1873. Two vols. London and Glasgow. Price, $1.50. For sale by Van Nostrand.

This is one of the numerous family of text books which many publishers have of late years issued broadcast, and it possesses the common characteristic of this class of work in being elementary and profusely illustrated with coarsely executed sketches. Indeed, besides the cuts in the first volume, which number 180, in 132 small pages, the second volume is made up of twenty plates, nearly the whole illustrating different modes of setting bricks, and to enhance their value the author says, "It is right to state that they have been, with few exceptions, *projected expressly for this work* from examples of small scale bricks laid down specially for our purpose." The italics are not our own.

We think that Mr. Burn might have spared his readers the first chapter on drawing, which is absolutely of no service, being too brief to serve those quite ignorant of the art, and too elementary for any ordinary lad to profit by after he has been a week in a drawing office. Plate I. of the atlas, also, is quite useless, consisting as it does of a number of badly divided scales, the intended purpose of which we do not understand.

Apart from these faults, we believe that Mr. Burn has written a little handbook that will be useful for reference not only to the student, but to builders, draughtsmen and intelligent bricklayers.—*Engineering.*

THE NEW CHEMISTRY. By JOSIAH P. COOKE. New York. 1874. Price, $2.00.

It is long since we read a work on chemistry which has charmed us so much as this of Professor Cooke, and the publishers are well deserving of credit for including it in their International Scientific Series. The mode of treatment adopted by the author is opposed to that of every other elementary treatise we know of, yet for giving a clear idea of the cardinal facts and theory of the science there is none equal to it save Hoffman's lectures on "Modern Chemistry." But Hoffman begins with experiment, and continues with beautiful and well-chosen illustrations to lay a foundation upon which he erects the theories and laws which are now generally accepted as governing and explaining chemical changes. Boldly reversing what the majority of us has always considered the natural mode of building up a science, Professor Cooke starts with a theory, the law of Avogardo and Ampère, and goes on through unaccustomed paths, occasionally throwing in a bit of heresy, *e. g.*, a doubt of the correctness of the wave theory of light—teaching his hearers and leaders certain dogmas in chemical physics, and forcibly impressing them on the mind long before he insists on a single chemical fact proper, or even gives them a single experiment or symbol. The success with which he has treated his subject is the best possible refutation of our previous prejudice against the mode he has adopted, though we are still inclined to think that only the equals of our author can hope to share this success. The book may be read with advantage by those belonging to the same class as the audience before which, in the form of lectures, it was first laid—namely, the intelligent but not professional, the style being lucid and the illustrations well selected. Students will also profit by its perusal, as it will teach them to think, and if they have been exceptionally well drilled in ordinary methods it will do something towards shaking their faith, and thus give them that desirable liberality of mind which holds theories loosely but facts firmly. It may even teach some how to classify facts for themselves—an accomplishment by no means so common among our uniformly manufactured students as it ought to be. We can add no more to our recommendation except the further one to our readers, that they cannot do better than peruse the book for themselves.—*Iron.*

MISCELLANEOUS.

THE THURSTON TESTING MACHINE.—REPORT OF NAVAL OFFICERS UPON ITS USE AND EFFICIENCY. Navy Yard, New York, May 2d, 1874. Vice Admiral S. C. Rowan, U. S. N. Comd't. Navy Yard, New York.

Sir:—In obedience to your order of the 25th ult., that we should proceed to the Steven's Institute of Technology, in Hoboken, New Jersey, and witness the operation of the Machine designed by Prof. R. H. Thurston of that Institute for testing the strength of materials, etc., to examine those in course of construction, to inspect the work already done, and the designs of machines proposed for special purposes, and to report in duplicate the results of our examination and our recommendation in view thereof.

We have the honor to report that, we have visited the Steven's Institute and witnessed the operation of a machine which has for its purpose to subject specimens of different materials to strains of torsion continuously from the initial strain through all the succeeding stages to final rupture; the machine being furnished with an automatic registry by which means the relation between the moment of torsion and the angle of tortion is graphically represented throughout the entire process of any experimental inquiry of the kind. We have also examined several machines in course of construction with improved features in the details of their operation, besides examining drawings of other and larger machines. We are satisfied that this form of Testing Machine admits of being used with great facility in the practical study of the properties of the woods, the metals and their alloys, especially with reference to their elasticity, ductility and ultimate resistance, that it is capable of revealing characteristic physical properties of great value in forming a practical judgment of their relative usefulness under different circumstances of their production or manufacture.

We find the machine an extremely simple one, and as small cost (estimated at $350.00 each), and, while we do not think it can judiciously replace the machines for direct tension, we are of the opinion that this machine would be found quite useful in the different departments of the Navy Yards requiring the kind of information furnished by it.

Signed, Robert Danby, Chief Engineer, U. S. N., W. L. Hanscom, Naval Const'r., U.S. N., Richard W. Meade, Commander, U. S. N.

ISOMETRICAL DRAWING.—At the last meeting of the British Association, Mr. George Fawens, of North Shields, read a paper on a new method he proposes for facilitating this manner of projection.

Isometrical drawing is supposed to represent a bird's-eye view of objects thrown back or forward at an angle of 30 degs. Right angles are thus extended or foreshortened 30 degs. in a manner somewhat similar to perspective drawing of square or cubes, the angles of 90 deg. being thus represented isometrically by angles of 60 degs. or 120 degs., and a square plane being drawn in a lozenge or diamond shape. In order to draw more readily lines intersecting each other at angles of 120 degs. and 60 degs., it is proposed by Mr. Fawens to use equilateral triangular-shaped boards with the ordinary T-square applied to the edges of the three sides. In an isometrical drawing these three sides will give lines corresponding in length, breadth, and height or depth. To draw a circle isometrically some simple methods are proposed; the circle drawn isometrically appears to be expanded or contracted to an elliptical or oval-shaped form, as is at once seen by cutting a cylinder or tube at an angle of 30 degs. It has been found that after setting off and squaring up on the △ drawing-board the two diameters of a circle, they are enclosed in a lozenge or isometrical square, and that the obtuse apex of this lozenge gives the centre for the drawing of the arc of a circle corresponding to the curve of the circumference of the minor axis between the points where the diameters of the circle touch the lozenge, the radius of which is given by the distance from the outer apex to these points; and the half of the minor axis gives the radius for completing the circles from these points by describing the end curves of the major axis of the ellipse of an isometrical circle, or these curves may be drawn freely by hand or with templates. To draw any other angles more or less right angles, a lozenge-shaped protractor is proposed. In this the lozenge is divided by two diameters parallel to the sides, into four isometrical squares; of these, the outer corners are divided for the angles of 45 degs., the outer sides of these squares are divided for divisions of 15 degs. each; these again subdivided into three divisions of 5 degs. each; these again minutely divided into five equal parts, corresponding each to a degree. This protractor gives at once right and left any required angle from the centre of the diameter parallel to the sides of the lozenge. For any angle from any base line not parallel to the sides of the lozenge, it is only necessary to take a diameter of the lozenge corresponding to the base line, and the required angles are set off from the centre of that diameter right or left. It is supposed that the use of equilateral-triangular copper plates and triangular blocks of boxwood will greatly facilitate the application of isometrical drawing to copper plate and woodcut engravings.—*Architect.*

[This method was described in the American papers some four years since.—ED.]

FINISHING WOOD WITH CHARCOAL.—The "United States Cabinet Maker" gives the following brief account of the method adopted by French cabinet-makers of producing a dead black on furniture and other work:—All the world now knows of those articles of furniture of a beautiful dead black color, with sharp clear-cut edges, and a smooth surface, the wood of which seems to have the density of ebony. Viewing them side by side with furniture rendered black by paint and varnish, the difference is so sensible that the considerable margin of price separating the two kinds explains itself without need of comment. The operations are much longer and much more minute in this mode of charcoal polishing, which respect every detail of the carving, while paint and varnish would clog up the holes and widen the ridges. In the first process only carefully selected woods of a close and compact grain are employed; these are covered with a coat of camphor dissolved in water, and almost immediately afterwards with another coat composed chiefly of sulphate of iron and nut-gall. The two compositions in blending penetrate the wood and give it an indelible tinge, and at the same time render it impervious to the attacks of insects.

When these two coats are sufficiently dry, they rub the surface of the wood at first with a very hard brush of couch-grass, or dog's-tooth grass, (*Triticum repens*) and then with charcoal of a quality as light and friable as possible, because if a single hard grain remained in the charcoal this alone would scratch the surface, which they wish, on the contrary, to render perfectly smooth. The flat parts are rubbed with natural stick charcoal, the idented portions and crevices with charcoal powder. At once, almost simultaneously, and alternately with the charcoal, the workman also rubs his piece of furniture with flannel soaked in linseed oil and the essence of turpentine. These pouncings, repeated several times, cause the charcoal powder and the oil to penetrate into the wood, giving the article of furniture a beautiful color and perfect polish, which has none of the flaws of ordinary varnish. Black wood, polished with charcoal is coming day by day to be in greater demand; it is most serviceable; it does not tarnish like gilding, nor grow yellow like white wood, and in furnishing a drawing-room it agrees very happily with gilt, bronzes, and rich stuffs. In the dining-room, too, it is thoroughly in its place to show off the plate to the greatest advantage, and in the library it supplies a capital frame-work for handsomely bound books.—*English Mechanic.*

THE largest crane in the world has just been erected at the docks at Barrow-in-Furness, by Sir W. G. Armstrong and Co., Newcastle-on-Tyne. It lifted 100 tons of rails with ease last September at the experimental trial.

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ON SOME EVIDENCES AS TO THE VERY EARLY USE OF IRON.

By ST. JOHN VINCENT DAY, C.E., F.R.S.E.

From "Iron."

The more extended our inquiries become concerning the state of some, at least, of the arts in ancient times, so have they always resulted in indicating an ever-increasing rise towards excellence in the ultimate product, in proportion as the examples cited belong to ages more remote from our own times. This assertion may doubtless be questioned by some; yet, as a point upon which those who have investigated high archæology appear to be agreed, that just mentioned seems to stand out as settled.

Many proofs of this may be found, but it is sufficient to signalize at present one or two—such as the architecture and sculpture of Proto-Egypt, Assyria, India and Greece—which, it is well known, never have been equalled in subsequent ages. That the artificers employed in executing the most ancient examples of mechanical execution in Egypt, were possessed of iron tools, (and as I shall presently show, almost certainly steel) my former paper was in part directed to prove.*

That iron was used by the Chaldeans, we have substantial proofs, although the examples which have come down to us are small and few; yet that is not remarkable when we remember the quickly oxidizing character of this metal in comparison with copper, silver, gold, etc. The Rev. Henry Rawlinson, in his "Five Great Monarchies," vol. i, pp. 98, 99, says, in reference to the metallurgy of the Chaldeans: "Metal seems to be scarce, and not many kinds are found; there is no silver, zinc, or platinum, but only gold, copper, tin, lead, and *iron*." . . . "Iron, as already observed, is extremely uncommon, and when it occurs is chiefly used for the rings and bangles which seem to have been the favorite adornment of the people."

When, however, we do find relics of iron manufacture among the ruins of the Proto-Chaldean kingdom, which had its period of chief activity and importance between 2000 and 1500 B.C., few though they be, and doubtless but a part of a large number of original examples lost through oxidation, we are led to infer that these, such as they are, have reached us owing to some peculiarities of position, which have interfered with the natural tendency to rapidity of oxidation attaching to iron.

When the seat of the Mesopotamian empire moved northwestward up the Tigris, and the Assyrians were the ruling nation, the testimony of Layard is conclusive as to their knowledge of the utility of iron.† In his other work,‡ Layard speaks still

* "Iron," vol. i, p. 739.

† Layard's "Nineveh and its Remains," vol. i, p 351, *et seq.*

‡ "Nineveh and Babylon," p. 191, *et seq.*

more assuringly as to the degree of skill acquired, and the extent to which iron was used by the Assyrians. It would appear that the Assyrians were unable to give elegant forms or pleasing appearance to objects in iron alone, and that consequently they frequently combined bronze and iron. Numerous interesting specimens of this nature are included in the collection of the British Museum. Of one of these, the foot of a tripod stand, found at Nimroud, Dr. Percy has made a careful examination: "It was a small casting, in the shape of the foreleg of a bull. It formed the foot of a stand, consisting of a ring of iron, resting on three feet of bronze. It was deeply corroded in places, and posteriorly was fissured at the upper part. A section was made which disclosed a central piece of iron over which the bronze had been cast. At the upper part, where it had been broken off, the iron had rusted and so produced the crack above mentioned. The casting was sound, and the contact perfect between the iron and the surrounding bronze. It was evident, on inspection, that the bronze had been cast round the iron, and that the iron had not been let into the bronze; and in this opinion I am confirmed by Mr. Robinson, of Pimlico, who has had considerable experience in bronze casting.

	Composition.
Copper	88.37 per cent.
Tin	11.33 "

"Some interesting considerations are suggested by this specimen. The iron was employed either to economize the bronze, for the purpose of ornament, or because it was required in the construction. If the former, iron must have been much cheaper than bronze, and, therefore, probably more abundant than has generally been supposed. No satisfactory conclusion can be arrived at on this point, from the fact that bronze antiquities are much more frequently found than those of iron; for the obvious reason that bronze resists, much better than iron, destruction by oxidation. Although I think there are reasons for supposing that iron was more extensively used by the ancients than seems to be generally admitted, yet, in the specimens in question, it appears to me most probable that the iron was used because it was required in the construction. And if this be so, the Assyrians teach a lesson to many of our modern architects and others, who certainly do not always employ metals in accordance with their special properties. The instrument under consideration, it will be borne in mind, was one of the feet of a stand, composed of an iron ring resting upon vertical legs of bronze. A stand of this kind must have been designed to support weight, probably a large cauldron; and it is plain that the ring portion should, therefore, be made of the metal having the greatest *tenacity*, and the legs of metal adapted to sustain *vertical* or *superincumbent weight*. Now this combination of iron and bronze exactly fulfils the conditions required. I do not say that a ring of bronze might not have been made sufficiently strong to answer the purpose of the ring of iron; but I do say that, in that part of the instrument, iron is more fitly employed than bronze"

The feet of certain tripod stands found at Nimroud—these consisting of a circular ring raised upon feet, to hold jars and vases—are frequently represented on the bas-reliefs. Layard describes the ring of one of them as being of iron, bound in some places with copper, while the feet were partly of iron and partly of bronze ingeniously cast over it. The iron inclosed within the copper has not been exposed to the same decay as that detached from it, and will still take a polish. From the Egyptian character of the designs, Layard suggests that it may be inferred that some of them were not Assyrian, but had been brought from a foreign people, who he appears, and very satisfactorily, to conclude were the Sidonians and other inhabitants of the Phœnician coast, the most renowned workers in metal in the ancient world, and whose intermediate position between the two great nations he considers, may have been the cause of the existence of a mixed art among them. It should not be passed over either, that, according to Herodotus and Pausanias, the Lydian King Alyattes, who died about 570 B. C., among other offerings dedicated to his god an inlaid iron saucer.

As I have previously dwelt upon the use of iron among the early Egyptians, and have produced both literary as well as material evidence of that use, it is only necessary to cite the conclusion at which Mr. Basil Cooper arrived in respect of the antiquity of that use by them from studies of a different order to those which I myself have more particularly pursued. He says:—"Turning to Egypt, we find that there also, as well as on the classical soil of Greece and Rome, the origin of the art of working

in iron is pushed back into the mythological and prehistoric age." We have no reason to doubt the testimony of Diodorus, when he repeats that the Egyptians assigned this invention also as well as all the other more important arts of life, to their great national culture divinity, Osiris. This, at least, implies that it was known among them from time immemorial.

I have already shown that the use of iron is identified with the time of erecting the oldest known Egyptian monuments, which, indeed, are by universal testimony proved to be the oldest on the earth; and, in view of the abundant evidence of a high yet peculiar civilization prevailing in that land in the remotest ages we can fathom, it has by many persons been assumed that most of the arts and sciences were spread therefrom among other peoples.

It is possible—nay, it is somewhat probable—that the knowledge possessed by the Proto-Egyptians of working in iron may have been brought with them from the Mesopotamian plains, whence they travelled westwards until finding the Nile Delta for a resting place. Yet, as bearing against that probability, we must remember that in the broad alluvial expanse, situate between the Euphrates and Tigris, they had not materials to work in, which demanded the use of iron or steel tools, such as they found when meeting with the Mukattam and nummulite limestones, syenites, porphories, diorites, and granites of the Nile valley. Yet, again, as strengthening the probability, we have the well-ascertained fact, that in the same alluvial soil the Proto-Chaldeans, and subsequently to them the Assyrians, practiced the art of working in numerous metals, including iron.

We may now pass down the stream of time to the Greeks, in the records of which people we find striking evidence of their acquaintance with the use and manufacture of iron. Indeed, as characteristic of that one-sided conceit which showed itself prominently through so many phases of the Greek mind, it is not surprising that, terming other nations "barbarians," the Greeks should attribute to themselves the discovery of iron, after the manner handed down to us in the Pelasgic tradition, connecting it with the Idæan Daktyls (Δάκτυλοι' Ιδαῖοι), professing that that discovery took place on the occasion of the burning of the forest which crowned their native mountain. The date of that conflagration, according to the Persian chronicle and other authorities, is the fifteenth century before the Christian era, or, more precisely, B. C. 1462.

Nor is the foregoing a solitary instance of literary testimony among the early Greeks as to their acquaintance with the metals. The shield of Achilles, described as of such excellent and intricate workmanship in the Homeric style, is another instance. While to Aristotle himself we are indebted for nothing less than an actual account of the mode in which the Greeks made steel in the fourth century B. C., proving them to have been acquainted with iron in the molten state also. The passage has been translated by Mr. Martin Lister, and reads thus:

"Wrought iron itself may be cast so as to be made liquid, and to harden again; and thus it is they are wont to make steel; for the scoria of iron subsides, and is purged off by the bottom; and when it is often defecated and made clean, this is steel. But this they do not often, because of the great waste, and because it loses much weight in refining; but iron is so much the more excellent the less recrement it has."

Somewhat obscure, no doubt, this Aristotelian passage is; yet when we carefully sift the nature of that which it conveys to us, it is replete with significance, as describing, very briefly and imperfectly, no doubt, what can scarcely be any other than a process of making steel used in Germany, certainly as late as the sixteenth century, that being proved by Agricola, who describes the process thus (*De re Metallica*, lib. ix.):—"Make choice of iron that is apt to melt and get hard, and may easily be wrought with the hammer; for though iron which is made of vitriolic ore, may melt, yet it is soft, or brittle, or eager. Heat a parcel of such iron red hot and cut into small pieces and then mix it with a sort of stone which easily melts; then set in the smith's forge or hearth, a crucible, or dish of crucible metal a foot and a half broad, and a foot deep; fill the dish with good charcoal, and compass the dish about with loose stones to keep in the mixture of stone and pieces of iron. As soon as the coal is thoroughly kindled, and the dish red hot, give the blast and let the workman put on, by little and little, all the mixture of iron and stone he designs. When it is melted, let him thrust into the middle of it three or four more pieces of

iron, and boil them therein five or six hours with a brisk fire; and, putting in his rod, let him often stir the melted iron that the pieces may imbibe the smaller particles of the melted iron, which particles consume and thin the grosser ores of the iron pieces, acting like a ferment to them, and making them tender. Let the workman now take one of the pieces out of the fire, and put it under the great hammer, to be drawn out into bars and wrought; and then, hot as it is, plunge it into cold water. Thus tempered, let him again work it on the anvil, and break it; and viewing the fragments, let him consider whether it looks like iron in any part of it, or be wholly condensed and turned into steel. Then let the piece be all wrought into bars; which done, give a fresh blast to the mixture, adding a little fresh matter to it instead of that which had been drunk up by the pieces of iron, which will refresh and strengthen the remainder, and make still purer the pieces of iron again put into the dish; every which piece let him, as soon as it is red hot, beat into a bar on the anvil, and cast it, hot as it is, into cold water. And thus iron is made into steel, which is much harder and whiter than iron."

The same process was also in use in the Island of Elba as late as A. D. 1683 (Kircher); and this place has been famous from the time of the Roman Empire for the production of steel.

From all the evidence we are led to infer that probably for about 3700 years the production of steel by immersing bars of wrought iron into a molten carburet of iron, was practiced among the nations in their progress westward—brought from Egypt, almost to a certainty, by the Greeks—established by them in the Mediterranean countries they occupied—whence it was acquired by the Romans, and by them introduced into their vast western empire.

From what Pliny had observed, and has handed down to us (lib. xxxiv., c. 14), it appears that the Romans in his time (*i. e.* in the earlier half of the first century of our era) were well versed in the practice of steel making by the same process; and seeing that he held the office of Spanish Procurator under Vespasian, it is at least very probable that his observations were made on the mode of manufacture established by the Romans in that country, wherein Toledo has been a famed seat for the production of swords of unrivalled temper and elasticity, from the time of the Romans until now. (I believe I am correct in stating, on the authority of Mr. Cockburn Muir, C. E., who has visited the place, that the Spaniards keep secret at the present time, the process by which their steel is made.) Toledo is a place well worthy of mention in these inquiries, seeing that the Roman army was provided with steel swords, many of them made here, with which they conquered the greater part of the known world, including these British Isles of ours, under Cæsar, B. C. 55.

When the archæology of India and China shall have been penetrated to its depth, we may hope to arrive at something more definite in respect of the practice in very ancient times of the art of iron-making; until that is done, much ignorance thereon is inevitable, and in view of what little knowledge we do even now possess, from the sparse nature of the information to our hand, even concerning comparatively late periods, we are led to hope for a great deal when the complete sources of testimony are bared to our vision.

A brief review of what we have already ascertained should be sufficient to convince the most skeptical how ignorant we are of the stages through which metallurgy has passed in the East; and in regard to this state of things Mr. Mallet has so well written, that I cannot do better than quote his *ipsissima verba*: "It is strange that of the iron metallurgy of Asia, the motherland of all the arts; of India, the country where, more than twenty centuries ago, King Parus presented to Alexander the Great, a *packa*, or wrought bar of Damascene steel, just as Homer's Achilles offered for a prize at the games of Patroclus, a like valued mass, whence the Greeks obtained the like 'wonder-working sword blades,' *θανριασια ξιφη* where steel dies were employed for coinage, when our ancestors were naked savages (I presume Mr. Mallet means "the ancient Britons," who were not our ancestors); of China, whence cast iron hollow vessels now reach us of a combined magnitude and thinness that we have not yet been able to imitate, or even imagine the process by which they have been cast, and razor steel said to surpass all European steel in temper and durability of edge; less is known than of the iron working of any other part of the civilized world—yet such is the fact.

"Central Asia, and even China, as yet

are nearly *terræ incognitæ*; but India, south of the Himalayas, has been more or less open to European observation for centuries, and has been in our own power for more than one. How little is known of the working of iron in China may be gathered from the bald and imperfect account of it given by MM. Stanislas Julien. Memb. Inst., and Paul Champion, Preparateur au Conserv. des Arts et Metiers, in their work on the 'Technical Arts of the Chinese Empire,' published in Paris in 1869; the first-named author, having a reputation as one of the first Chinese scholars in Europe; and the second being a competent metallurgist and technologist. Yet China possesses the knowledge of working in fluid cast iron, as well as in wrought iron and steel—the first being, at the present day at least, commonly reported to be unknown in India, where wrought iron is made direct from the ore, and steel also."

Judging from what we gather among the mountains of India, the working in iron in very large masses was carried on there many centuries since, for at the mosque of Kuttub Shaw, in or near Delhi, is standing at this very day an iron column which is described by Colonel A. Cunningham in the archæological report to the Government of India for 1861-2.

"Art. 65. The Delhi pillar is a solid shaft of mixed metal upwards of sixteen inches in diameter, and about fifty feet in length. It is true there are flaws in many parts, which show that the casting is imperfect; but when we consider the extreme difficulty of manufacturing a pillar of such vast dimensions, our wonder will not be diminished by knowing that the casting of the bar is defective. The total height of the pillar above ground is 22 ft., but the smooth shaft is only 15 ft., the capital being 3½ ft., and the rough part of the shaft below also 3½ ft. But its depth underground is considerably greater than its height above ground, as a recent excavation was carried down to 26 ft. without reaching the foundation on which the pillar rests. The whole length of the iron pillar is therefore upwards of 48 ft., but how much more is not known, although it must be considerable, as the pillar is said not to have been loosened by the excavation. I think, therefore, it is highly probable that the whole length is not less than 60 ft. The lower diameter of the shaft is 16.4 in., and the upper diameter is 12.05 in., the diameter being .29 of an in. per foot. The pillar contains about 80 cubic feet of metal, and weighs upwards of 17 tons."

With regard, then, to the constitution of the metal of which this remarkable shaft is composed, Colonel Cunningham erroneously described it as "cast metal;" and it does not appear on the face of his report that he personally examined the shaft itself, but probably relied upon what was conveyed to him by others, guided, possibly to some extent, by the very mystifying account given of it by Mr. James Furgusson in his "History of Architecture," vol. ii, p 460, where the column is described in one line as "wrought iron," and in another as a "single casting."

There is much confusion in the different accounts I have met with as to the precise building in which the iron column is situated. The column itself is usually called "Kuttub Minar," yet according to the account in the "Asiatic Researches," vol. iv., p. 727, by Ensign J. T. Blunt, the "Kuttub Minar" is a stone building between 240 and 250 ft. high, built by the Emperor Shaw Jehan in the present city of Delhi; and it appears from this account that this minar—minaret—was erected at the expense of Kuttub Shaw, whose tomb is situated a few hundred yards westward of the minar.

This Kuttub Shaw came to the throne of Delhi in the Mussulman year 602, corresponding with the Christian era 1205; but the iron column itself is vastly older than this stone building, as will be seen hereafter. It is specially desirable that the confusion which exists on this point should be cleared up; and, by way of anticipating what is probably the fact, we may presume that the column, pillar, or Laht referred to, is within the precincts of the enormous, never-completed, still unfinished mosque, named after the founder of the aforesaid stone minar.

I am much indebted to Colonel H. Yule for a sketch of this remarkable Laht, and also for valuable references to the literature bearing upon it. In a letter to me he says, "There is an inscription on it ascribing its erection to an otherwise unknown Raja Dhaoa. The character of the letters is considered both by Prinsep and Cunningham, to refer it to the third or fourth century of our era. It also bears later inscriptions. Prinsep calls it a 'monument of skill in *forging* iron, for the pillar is a well-wrought circular shaft of iron of considerable mag-

nitude.' Cunningham again speaks of it as if it were *cast*. It is a pity the thing is left so obscure. I have seen the pillar twice or thrice, and it certainly seemed to me a shaft of wrought iron to all outward appearance. But, query, whether, if it were really iron, the surface could have remained as perfect as it is—polished, and bearing the superficial inscriptions—for 1600 years?

"It is mentioned by the Arab traveler, Ibn Butata, who was at Delhi *circa* 1340. He says: 'In the middle of the mosque you see an enormous pillar, made of some unknown metal. One of the learned Indians told me it was what is called *Haft ush, i.e.*, 'seven metals,' being compounded of so many different metals. The pillar has been polished on a surface about as long as one's forefinger, and this part shines brilliantly. Iron leaves no marks upon it. Its length is thirty cubics; we encircled it with the cloth of a turban, and found the girth so measured to be 8 cubits.' The Arab's *girth* is greatly exaggerated; so probably his *length* is also an exaggeration of the height above ground, and bears no reference to the actual entire length, which we see to be more than 30 cubits."

With the object of deciding whether the iron was "cast" or "wrought," a fragment has been cut from the pillar, and not long since sent to England, a portion of which is said to have passed into Dr. Percy's hands; and this he (Dr. Percy) had heated and drawn out on an anvil, after which he (Dr. Percy) pronounced it to be forged "iron."

Strangely divergent, however, from the account given by Colonel Cunningham (already quoted), is that which has appeared in the "Journal of the Iron and Steel Institute," where, on the authority of Lieutenant Spratt, R. E, said to have been stationed at Delhi, certain statements are published which are utterly contradictory of those given by Colonel Cunningham. Whether in the main Colonel Cunningham's account or that of Lieutenant Spratt be correct, I am not at present in a position to determine. I am, nevertheless, bound to point out that in dealing with the question, either Lieutenant Spratt or Mr. David Forbes, F.R.S. (the writer of the Iron and Steel Institute's Report), is at fault in respect of his representation of that which Colonel Cunningham has really written.

One or other of these gentlemen ["Iron and Steel Institute Journal," vol. i., p. 151] represents Colonel Cunningham to have reported, and Mr. Mallet to have repeated, that the above-ground height of the column was 48 ft.; whereas in both Colonel Cunningham's report and Mr. Mallet's account, that is the total height of both the above-ground portion and that below ground, to the depth reported to have been excavated; but now, according to Lieutenant Spratt, the above-ground portion is 24 ft., or 2 ft. higher than that portion is reported by Colonel Cunningham, while in regard to the below-ground portion, it is not only very short indeed, but of a complex character, contrasting strangely and irreconcilably with the description handed to us by Colonel Cunningham.

The account to which I allude reads thus: "The height of the column above ground is only 24 ft., and 3 ft. below ground it ends in a bulb like an onion, which is held in its place by eight thick rods of iron, on which it rests, and which at their lower extremity are let into blocks of stone in which they are secured by lead. The iron of which it is made, which appears to have been originally in blooms of about 50 lbs. weight each, has been examined by Dr. Murray Thomson, of the College at Roorkee, who found it to be wrought iron, possessing a specific gravity of 7.66."

With respect to the material of which the pillar, alleged to be one and the same, to which both the afore-mentioned reports appertain, is composed, they agree; but it inconceivable that an officer and archæological surveyor to the Government of India of Colonel Cunningham's reputation, could be so far led away from facts as to report, certainly the most remarkable relic of ancient iron metallurgy yet discovered, in the loose and false style he clearly has done, if Lieutenant Spratt's account be the correct one.

The discrepancies to which I have directed attention certainly suggest the possibility of two different iron pillars existing in or near the city of Delhi, and that some confusion has resulted on that account; but as we have at present no certain evidence of more than one such column, and considering the complex, and really, even now-a-days, most-difficult-to-produce character of the forging, as it is described by Lieutenant Spratt, we must, in the absence of more precise information—in view, too, of the palpable blunders in the report of the Iron and Steel Institute as to Colonel Cunning-

ham's statements—prefer Colonel Cunningham's account, as being most probably nearer the truth.

Having thus, I trust, judged impartially in respect to the real form of this monument, the next point we have to deal with is the date of its construction. For this I again refer to Colonel Cunningham's report, Art 66, *et seq.*, in which he concludes for that event the year 319 A.D.

"66. The iron pillar records its own history in a deeply cut Sanskrit inscription of six lines on its western face. The inscription has been translated by James Prinsep, who remarks that, 'the pillar is called the arm of fame of Raja *Dhava*, and the letters cut upon it are called the typical cuts inflicted on his enemies by his sword, writing his immortal fame.' It is stated that he subdued a people on the *Sindhu* named *Vahlikas*, who must be the *Bahikas* of the Panjab; and, lastly, that he obtained with his own arm an undivided sovereignty on the earth for a long period.' The above is the whole of the meagre information that can be gathered from this inscription, save the bare fact that the Raja was a worshipper of Vishnu. The date of the inscription is referred by James Prinsep to the third or fourth century after Christ; but Mr. Thomas considers that this is 'too high an antiquity for the style of the writing employed on the monument.' I agree, however, with Prinsep, as the characters appear to me to be exactly the same as those of the Gupta inscriptions. I have already suggested the year A.D. 319, which is the initial point of the Balabhi or Gupta era, as an approximate date for Raja *Dhava*, as I think it not improbable that he may have assisted in the downfall of the powerful Gupta dynasty.

"According to universal tradition, the iron pillar was founded by *Bilan Deo*, or Anang Pal, the founder of the Tomara dynasty, who was assured by a learned Brahman that, as the foot of the pillar had been driven so deep into the ground that it rested on the head of *Vásuki*, king of the serpents, who supports the earth, it was now immovable, and that dominion would remain in his family as long as the pillar stood. But the Raja doubting the truth of the Brahman's statement, ordered the pillar to be dug up, when the foot of it was found wet with the blood of the serpent king, whose head it had pierced. Regretting his unbelief, the iron pillar was again raised; but owing to his former incredulity, every plan now failed in fixing it firmly, and in spite of all his efforts it still remained loose (*dhila*) in the ground; and this is said to have been the origin of the name of the ancient city of *Dhili*.

"This tradition has been variously reported by different authorities, but the main points are the same in all. . . The popular belief in this tradition is confirmed by the well know verse:

Killi to dhilli bhai,
Tomar bhaya mat hin.
The pillar became loose by Tomar's folly.

Kharg Rai relates this tradition in a more poetical form, making the date the Samvat year 792, or A. D. 736."

With further respect to this column, several writers appear to have confounded it with the stone column, known as Feroze Shah's Laht, described in the "Asiatic Researches," vol. i., p. 371, as the following will show:

"At ancient Delhi," says Bacon, "there is an extraordinary pillar, apparently metallic, but is really of red sandstone, bearing a silvery bed in it, now called Feroze Shah's Laht, or walking stick. *Thirty feet of it are above-ground*, and buried many feet in the earth. There is one exactly similar to this at the Cootub Minar, and another at Allahabad. All are supposed to be of the same origin, but their history is quite lost in obscurity. They are covered with inscriptions. Forrest mentions that this pillar at the Cootah Tower is of solid iron, and that the whole temple is a subject of great doubt and incertitude."

A learned correspondent, too, writes me in respect of this iron column: "The inscriptions thereon are of *different dates*. Some, the most ancient in Ragari letters, others in Sanskrit, all prefaced by the mystical Holy Invocation O'M. The events engraven involve very great periods, thus one is decidedly the year of Christ 67 (by computation).

If this last account then has reference to the column described by Colonel Cunningham, (which I am bound to say I doubt), it is unquestionably much older than he concludes. I am of opinion, however, that it relates to the red stone Laht of Feroze Shah, and, therefore, has no reference to the iron column. In the midst of such conflicting or rather confused testimony, which is all we yet possess, I conceive it would be unwarrantable to attempt to fix the date of

this remarkable work. The utmost then at which we can now arrive is, that its antiquity is very considerable. This conclusion being arrived at not only by reason of the absence of any precise generally current information regarding it, but judged of also from the universal testimony throughout the East, both in material and literary relics, of a very remote and, contemperaneously, very high intellectuality then prevailing.

As to how this remarkable forging was produced, some have been bold enough to conjecture. For the present I abstain from offering an opinion, but as a suggestion, indicating what may be at least a probable mode in which large pieces of iron were produced in ancient times, I refer to the account presented to us by Mr. Alfred Russel Wallace, of the manner of producing the "sacred krisses" in the Island of Lombock.

These were made at taking of a census, the Rajah commanding a needle to be brought him from each head of the population. These needles were collected by the chiefs in the various villages and towns, and a bundle sent from each to the Rajah, which contained a number of needles corresponding to the number of the people; and when it was quite certain that every village had sent in its bundle, the Rajah divided the needles into twelve equal parts, ordered the best steel worker in Mataram to bring his forge, his bellows, and his hammer to the palace, and to make twelve krisses under the Rajah's eye, and in sight of all men who chose to see it.

Whether, then, the iron column at Delhi is the result of taking a census after the manner adopted by the Rajah of Lombock, I must leave to others to determine; but that it is a monument in commemoration of some grand event, or of some high religious belief and practice, no one, I presume, will attempt to question.

Mr. Mallet, after carefully reviewing the evidence as to whether this huge specimen of ancient ironwork be a casting or a forging, says:

"We are thus obliged to consider that this pillar is not a casting, but a huge forging in native Indian or other Asiatic-made wrought iron, and if so, the question arises how was it forged? We have no evidence that 'blooms' of more than 90 lbs. or 100 lbs. each were ever made by modern methods; these would be too small to build up singly into a bar of 16 inches diameter. It is, however, conceivable that such little 'billets' as were procurable from such blooms might be welded into bars, and these bars made into a faggot, out of which such a bar, by sufficient means for bringing it to a welding heat, and for then hammering it, might be welded into a cylindrical bar such as that of this iron pillar.

"Now, the limit to the size of a faggot that can be welded with given means of heating it, is found to be when the mass is so great in proportion to the power of the furnace that the exterior of the mass, when the heat is being applied, oxidizes and melts away (owing to the slowness of heating, and hence long continued exposure to the heat) as fast as piece after piece is laid on to make up for the waste.

"This limit has been reached before now even in our best reverberatory forge furnaces; it actually was touched upon at Liverpool, in forging the Mersey Company's great 12-inch gun. Unless, therefore, the ironworkers of India, between the third and fourth century, A. D., possessed air-furnaces and lofty stalks or blowing apparatus of some sort, upon a scale now unknown, and, indeed, not conceivable in any form of native apparatus, we may confidently affirm that no faggot to form a welded bar of 16 in. diameter could have been by any possibility brought to the welding heat at all, or without such waste as to prevent it ever being forged.

"If we pass from the heating of such a bar to the forging of it, our difficulties are still greater. The limit in size of *hand-forged* work in Europe was about reached in the production, in days gone by, of the heaviest 'best bower' anchor of a ship of the line. The largest section of the anchor shank, when welded to the arms, was about 8 in., or perhaps 9 in. across, and the welding was effected by the blows of twenty-four 'strikers,' trained to strike in time, and swinging 14-lb. to 28-lb. sledges. The shower of blows dealt for some minutes' spell upon the mass of iron of this large section produced a very insignificant effect, so that both the faggoting and the welding of such anchors were often very defective, and the strikers having to stand close in a ring, within the short distance for swinging the sledge from the glowing iron, were greatly scorched by its radiated heat, and some with fine skins were unfitted for the work. Hereabouts, then, the limit to

hand-forging was reached, both as to the power of the hand-sledge to act upon the mass of iron, and as respected the power of the men to endure the heat radiated from the glowing iron at the short distance from it, limited by the length of the handle of a sledge when swinging.

Now. the section of the shank of a "best bower" of 8 or 9 in. diameter, is to that of the Delhi iron pillar, about as 64 to 201—*i. e.*, the latter would radiate from its heated extremity more than thrice as much heat, and an equal length would be more than thrice as great a mass to be dealt with by the sledge-hammer, than in the case of the anchor. We may, therefore, affirm that, even in European hands, a bar of wrought iron of 11 in. diameter could not be welded up by hand labor with the sledge. The latter would produce no adequate impression—least of all in the comparatively feeble hands of Asiatics—and human skin and muscles could not withstand, at five or six feet off, the intolerable glare and scorching of such a mass heated to the welding point.

How then was the Delhi pillar forged in India, even assuming that some means for heating it existed? Forging by power in some form of course suggests itself, but upon what source of power can we even speculate? Human muscles, and the "bullock walk" by which the water-skins, or "bheesites," are drawn up from the wells or tanks, appear to be the only present sources of power in India.

The water-wheel, or *noria*, for raising water by the application of such animal power is common; but the production of power by the descent of water on a wheel seems never to have been known in India, where, indeed, except in the hill districts, no falls for water-power exist. The windmill, though said to have been known in Persia from some very remote period, has never been seen in India, and it need scarcely be said steam-power is out of the question.

It is barely imaginable that some form of falling tup-hammer raised by men acting by ropes, after the manner of the old singing-engine for pile-driving, may have been employed, or some rude form of tup or tilt-hammer, moved by bullocks, acting on a walking-wheel. It is for Indian archæologists to discover if there be any records or traditions of such appliances, without which the methods by which this huge pillar was forged must remain inexplicable.

The pillar itself stands before us, so far, a metallurgical enigma. If it stood alone, and were this great ancient forging in wrought iron alone known to exist in India, we might pass it by, content to suppose it too isolated an instance on which to found any conclusions as to the iron metallurgy of that country in former ages; but, although little noticed, and apparently quite unknown to our European writers on iron metallurgy, other examples likewise exist.

Not to lay any stress on the probable existence in India of other iron pillars, as affirmed to the writer by an accurate Indian officer well acquainted with the country, the following facts are recorded by Mr. James Fergusson in his "Illustrations of Ancient Architecture in Hindostan:"—

"In the Temple of Kanaruc, or Black Pagoda, in the Madras Presidency, the walls of the *mantapa*, or porch (which is about 60 ft. square inside) are about 10 ft. in thickness, and the depth of the doorways is, consequently 20 ft., and their lintels are supported by large iron beams of about 1 foot section laid across from side to side. The roof is formed after the usual bracket-fashion of the Hindus, each course projecting beyond the other, so as to give (from the inside) the appearance of inverted stairs. . . At about half the height, where its dimensions narrow to about 20 ft., a false roof has been thrown across, the remains of which now lie heaped up as they fell on the floor of the apartment. Among them may still be remarked several beams of wrought iron about 21 ft. in length and 8 in. section, and a great many blocks of stone 15 ft. and 16 ft. long (and they were probably broken in their fall), and of a section 6 ft. by 2 ft. or 3 ft." Here then, we have employed as mere building material wrought iron bars of 8 ins. square and 21 ft. long. Mr. Fergusson views this temple as having been built between A. D. 1236 and A. D. 1241.

In another temple examined and described by Mr. Fergusson—that of Mahavellipore, standing alone on a solitary rock of granite projecting into the very surf on the coast, near Madras, and the date of which he refers to the tenth or eleventh century, A. D., but which he deems may be as late as the thirteenth or forteenth century (described in his great work as above, p. 57, and plate viii.)—he informs me

there are empty sockets for beams, like those just noticed; the beams, he justly argues, must have been of iron, as the sockets show a scantling, which would have been, if in timber, perfectly useless under the load carried.

It is highly probable that at Kanaruc the ceiling beams thrust themselves out of their sockets by alternate expansion and contraction, and so brought down the "false roof," as the filling above is called; but the place affords a bad foundation, and is said to be subject to earthquakes. However, our business with these iron beams is simply as metallurgic monuments. Here then, we have the fact, that at Delhi in the north, and at Madras, in the far south of India, massive forgings exist, such as all Asia, so far as we know, could not produce at the present day, and of a size rivalling those upon which Europe to-day prides itself.

The earliest of these dates from the third or fourth century, and the latest from the eleventh to the fourteenth centuries of our era. With such an interval of time as 900 to 1000 years, and such a diffusion in space as from north to south of India, it seems impossible not to conclude that the evidence of these monuments attests the existence in India for that long period of a great iron manufacture, well established, and with a relative cheapness and certainty of product that admitted of the use of iron as a material for public monuments, and as a building material in sacred edifices, and that this manufacture was extinct, and the art and methods lost, long before any modern European occupation of India. So that far from Indian iron-working having been from time immemorial the same feeble thing we see it to-day, it was once a great and flourishing craft, and extended over parts of the entire Indian peninsula.

Nothing heretofore brought to light in the history of metallurgy seems more striking, to the reason as well as the imagination, that this fact: that from the remote time when Hengist was ruling in Kent, and Cerdic landing to plunder our barbarous ancestors in Sussex, down to that of our Third Henry, while all Europe was in the worst darkness and confusion of the Middle Ages—when the largest and best forging producible in Christendom was an axe, or a sword-blade—these ancient people of India, the forerunners of those now so enfeebled and so degraded, possessed a great iron manufacture, whose products Europe, even half a century ago, could not have equalled.

Yet these conclusions rest on no new facts, but on the colligation of old ones by the light of practical knowledge. Indian archæologists and writers have long known of the existence of these iron monuments of an ancient and lost art in India, but their importance has, the writer believes, not before been recognized as bearing on ancient oriental metallurgy. The reason of this is, that those who have examined the monuments of India, however scholarly and able in many ways, have not been metallurgists, and have had no practical knowledge of iron working. The ancient, and indeed the existing technology, at large of India—still more of Asia at large—remains almost unexplored and undescribed; and whenever it shall be examined, analyzed, and described by really competent men, (and such have never yet been commissioned with the task), results even more strange, and perhaps of more importance, historical and practical, than those deducible from the Delhi iron pillar, will, no doubt, come to light.

A notice by M. Lévog, a mining engineer resident in Japan, of the iron-workinig districts of that country, may throw some light on the conjectural modes by which these great forgings may have been effected by human power in these remote ages in India.

In reference to the mode of iron-working in the mining province of Ykouno, M. Lévog says:—"The treatment employed is a sort of imperfect Catalan method . . . . . but what distinguishes the Japanese method from that of Ariege is, that they treat at once 16,000 kilos. of ore, and produce an enormously long pig of 1300 kilos., which is broken up under a huge hammer, constructed after the style of a pile-driving ram, to which motion is given by a walking-wheel of 11.5 metres diameter, acted upon by men. One can see that potent blows may thus be given, but their frequency and regularity do not seem such as to admit of a forging being thus produced, even if the means for heating a mass as huge as those referred to were capable of being guessed at." Thus far, Mr. Mallet.

With respect to the evidence which the literature of the ancient world has to offer in proof of the extreme antiquity of the use of iron, that evidence is considerable and wide-spread; and as the region of research has already been so extensively explored by

the learned and cultivated Goguet, I shall content myself with now briefly running through what he has collected.

He says:—"The invention of the hammer, anvil, and pincers, was placed by the ancients in the remotest ages. The Egyptians attributed these inventions to Vulcan, others gave this honor to Cyrinas, the father of Adonis (Pliny, 1. 7, section 57), which makes them no less ancient."

I may here remark, that this worship of Vulcan was well established, particularly in Egypt, at Athens, and at Rome. His forges were supposed to be under Mount Ætna, in Sicily. Vulcan was generally represented as covered with perspiration, blowing with his arm the fires of his forges, at other times holding a hammer raised in the air ready to strike, while with the other hand he turned with pincers a thunderbolt on an anvil.

Goguet continues:—"The art of forging metals, without any doubt, was known in Egypt, and some parts of Asia, in the most distant times. We see arms of metal in use in Palestine, a few ages after the Flood. Moses says that Abraham drew his sabre to sacrifice his son Isaac. The ancient Patriarchs shearing their sheep is a further proof that the fabricating of metals was then well understood. They knew even then how to execute works in gold and silver, which require delicacy and exactness. In a word, we see everything relating to metals, the places where they are found, the manner in which they are wrought, etc., exactly described in the book of Job."

Arguing as a pure rationalist, and as one unacquainted with the practice of working in metals, Goguet is here led off into that favorite but mistaken theory which has taken firm hold upon the minds of those who are versed in the literature only of metallurgy, and he proceeds to argue that *ex necessitate*, mankind would begin to work with "such metals as were most easily procured and fabricated," and he cites gold, silver, and copper as examples, because "considerable masses of these metals were sometimes found pure and without mixture," and "that they were easily melted and refined. For these reasons," he says, gold, silver, and copper were the first metals that were wrought;" and he adds, "but the finding and working of iron must have been a very late and difficult discovery. Without doubt, it was the last of all the metals mankind were acquainted with, or knew how to use.....In reality, the greatest obstacle to the use of iron was the difficulty of making it. Iron, of all metals, is the most difficult to bring into fusion.

In these very words and some others which occur in M. Goguet, bk. ii. chap 4, entitled, "Of the Discovery and Working of Metals," we find nothing less than the identical doctrine propounded in France more than a century ago, which has been revived in these latter days, namely, that of the successive use by man of stone, bronze, and iron, and which has received the support of so many and such noted persons.

That this doctrine is untenable, I have shown in a former paper; and as to the difficulty started by those who argue from mere book knowledge, I have already pointed out from the facts of metallurgical science, that fusion is not essential to the reduction of iron into the metallic state—that, in fact, to reduce it is one of the simplest and most readily occurring results in the whole range of metallurgic art, that, in fact, the most wide-spread practice of reducing iron is effected without fusion.

As if to make the difficulty set up concerning the necessity of fusing iron in order to work with it and convert it into tools, weapons, etc., still greater, Goguet, as if following after or leading on the *litterateurs*, adds, "Besides one single melting is sufficient to render gold, silver, or copper, ductile or malleable. It is not so with iron. A piece of this metal once melted is as untractable as ever, and not more ductile than a flint. In this state it is hard and brittle, and cannot bear the hammer either cold or hot. The file, the chisel, and the graver, can make no impression upon it. In order to forge iron, therefore, it was necessary to find out the art of softening it, and rendering it ductile. To do this, it must be melted a second time, then beat with very heavy hammers; this mass must be put in the furnace and heated till it is upon the point of fusion, then put again in this state under the hammer; this operation must be repeated several times; at last this hard and brittle mass, by frequent heating and hammering, becomes forgeable."

And yet, M. Goguet, with all this plausible argument against an extremely ancient use of iron, in the end finds it insufficient and directly contrary to the evidence with which he has dealt, so that he concludes his researches in the following words:

"In maintaining, however, that copper originally supplied the place of iron, I do not pretend to affirm that the last metal was altogether unknown in the ages we are now upon. Several testimonies give us reason to believe that some nations knew the art of working iron in very ancient times. There was a tradition among the Egyptians (already mentioned) that Vulcan taught them to forge arms of iron. (Chron. Pascal, p. 45, C.; Cedren., fol. 19 D.) There is a manifest contradiction in Cedrenus. For after he has said that Vulcan taught the Egyptians to forge arms of iron, he adds that, having obtained pincers by his prayers from heaven he used them in working copper. The Phœnicians also ranked among their most ancient heroes two brothers who were supposed to have discovered iron, and the manner of working it. (Sanchon, *apud* Euseb., p. 35.)

The Cretans, as Diodorus relates, placed both the discovery of iron and the art of working it in the remote periods of their history. The inhabitants of Mount Ida pretended to have learned the art of working this metal from the mother of the gods. (Sophocl. *apud* Strabo, l. 10; Diod. l. 17.) In a word, Prometheus, in Æschylus, boasts of having taught mankind the fabrication of all metals.

"Some authors ascribe the discovery of the art of working iron to the Cyclops (Pliny, i. 7, sect, 57) and some to the Chalybes (Ammian, Marcell., l. 22, cap. 8; Schol. Apollon. *ad.* l. 2), a very ancient people, renowned for their skill in working this metal (Virg. Georg. l. 1, v. 58; Æschyl., 'In Prom. vinct.,' v. 501). The Chalybes inhabited the south coasts of the Euxine sea between Colchis and Paphlagonia. Clemens Alexandrinus pretends that the art of making iron malleable was found out by the Noropes. This nation was situated in Pannonia, along the banks of the Danube, between Noricum and Mæsia.

"Without entering into any discussion of these traditions, which are all beset with great difficulties and contradictions, it appears, from the Book of Job, that the art of working iron was known in some countries long before the ages we are now speaking of (Job, chap. xix, 23, 24: 'O that my words were now written! O that they were printed in a book! That they were graven with an iron pen and lead in the rock forever!' Chap. xx. 24: 'He shall flee from the iron weapon, and the bow of steel shall strike him through.' Chap. xxviii. v. 2: 'Iron is taken out of the earth, and brass is molten out of the stone.' Chap. xl. v. 18: 'His bones are as strong pieces of brass; his bones are like bars of iron.' And chap. xl. 27.)

"The books of Moses also furnish us with very strong proof of the antiquity of this discovery. From the manner in which this legislator speaks of iron, it appears that that metal must have been in use in Egypt long before his time. He celebrates the hardness of it (Lev. xxvi. 19; Deut. xxviii. 23 and 48), and take notice that the bedstead of Og, King of Bashan, was of iron; he speaks of mines of iron (Deut. viii. 9: 'A land whose stones are iron, and out of whose hills thou mayest dig brass'); he compares the severity of the servitude of the Israelites in Egypt to the heat of a furnace for smelting that metal (Deut. iv. 20). But what is most worthy of our attention is that they then made swords (Numb. xxxv. 16), knives (Lev. i. 17), axes (Deut. xix. 5), and tools for cutting stones (Deut. xxvii. 5), of iron. To make the blades of swords and knives they must have known the arts of tempering and turning iron into steel. These facts seem to me sufficient to prove that the discovery of iron, and the arts of working it, were extremely ancient in Egypt and Palestine."

After all, then, that has been advanced, I unhesitatingly ask, are not the proofs both literary and material which have been now (I believe for the first time) collected together, corroborative of each other? Do they not demonstrate that in the very earliest ages we can fathom, iron was used and well known? Relying upon the Hebrew records, it is thoroughly attested that very many (possibly all) of the metals were used simultaneously in the very earliest ages. That numerous other proofs are in existence I have little doubt, but I must leave their collection to others having more leisure than has fallen to my lot. I do hope that I have at least demonstrated, in respect to this one particular material, how pre-eminently unsafe it is in drawing conclusions as to the state of arts in remote past ages, to assume as universal that which appears at most as probable only, from the material relics met with in some countries only.

I am further bound to say, that those who have so concluded in modern times, seem to disregard altogether what ancient authors have recorded, thinking only to

satisfy some favorite theory. Such procedure is not only blinding at the first, not only never can evolve the truth, but must inevitably tend further and further from that sublime region.

In conclusion, I feel that I cannot express what I wish finally to convey, as the issue to which the investigation points, more fitly than in the words of my cultivated and talented correspondent. Mr. Robert Mallet, F. R. S., who in writing to me on the subject of ancient ironwork, says:—"It is a subject on which the usual, if not orthodox, views of achæologists generally seem to me as very superficial. They all seem to forget that at all times, as now, civilization was simultaneously at various stages in different parts of the world. When flints were the best tools of northwest Europe, iron and steel may have been those of peoples far to the east. As in palæontology, you can fix no horizon common to all the world at any time."

Dr. Percy, one of the foremost living authorities on the metallurgy of iron, in writing to me from the House of Commons, under date July 5, 1871, quite as appropriately expresses himself:—"I become more and more confirmed in the opinion that archæologists have been generally mistaken concerning the so-called 'Iron Age.' I am collecting further information on the subject from time to time, and as yet have met with nothing of late in opposition to the opinion above mentioned."

WORKING VERY HEAVY GUNS.

From "Engineering."

Guns are rapidly increasing in size and weight. The 35-ton gun is indeed a mere "infant," compared with some of the weapons now proposed, if not actually constructing, both at home and abroad. Unfortunately, side by side with this great increase in power, the rapidity with which these tremendous weapons can be worked by manual power alone, and consequently with which they can be fired, notably diminishes as they grow in size.

Without entering on the question of the tactics of a future action at sea, or endeavoring to fix the precise speed at which ships will engage, opinion on both sides of the Channel may be said to concur in the adoption of the "end-on" mode of attack as the proper basis of all evolutions. Ships, it is said, will advance at great speed to attempt the fatal ram or torpedo attack against floating fortresses comparatively impregnable to artillery. Looking to the conditions of such a battle, and the present rate of working the heaviest guns, a French writer, Admiral Jurien de la Gravière, affirms that silence should be imposed on the guns of a ship until close alongside the enemy.

To avoid so restricted a field of action for a very considerable portion of a ship's offensive powers, the following conditions must be fulfilled:

1. Great rapidity in working the guns.
2. Large vertical arcs of training, with power of moving very quickly through them.

These two conditions are absolutely necessary in a naval combat of the future. Neither of them are satisfied at present in the English navy.

If the time during which artillery can exert its full power is so much shorter than in the days of wooden ships, owing to the very rapid movements of the ships engaged, it is evidently of the first importance that the rate at which the guns can be worked should be at least equal to that of the weapons of those days, certainly not inferior.

It is from this point of view that the recent admirable application of hydraulic power to all the movements connected with loading and running in or out very heavy guns, designed by Mr. Rendel and explained by him at a recent meeting of the Institution of Civil Engineers, is of the greatest value, and as the comparative advantages of such a system over the methods of working heavy guns actually in force at present are perhaps, as far as the details are concerned, but little known, we propose to devote a short space to their consideration. We shall also indicate a further important development in the mechanical working of heavy guns which can be brought about by the use of hydraulic power, and which completes the proposed method of working guns by this means.

First, let it be said that huge guns of this nature are now almost universally placed either in turrets or in barbette towers. In turrets, two guns are usually mounted side by side, in barbette towers one only is placed.

It is difficult to see what advantage is gained by placing two guns in a turret instead of one heavier gun. Could the two be worked as well as if fired independently, the rate of fire would certainly be increased, but it is practically impossible to load one gun in such close proximity to another monster which is being fired. Flesh and blood cannot stand the concussion, even if the danger of sparks entering the port is overlooked. It is therefore only possible to fire the guns simultaneously, and if this is the case it is probable that one heavy gun would be better than two lighter ones. The destructive effects of a shell from a 70-ton gun would be much greater than that of two from 35-ton guns, while it could penetrate a structure which would defy the lighter guns. With a single, also, there would be far more room in the turret for working the gun, while the strength of the turret itself would be greater from having only one hole in it instead of two.

Those who witness the various movements of guns mounted in turrets—as now fitted—performed independently and without reference to each other, are apt to attribute a far greater rate of speed to the firing of the gun than can be obtained when the movements are simultaneously performed in the manner in which they actually occur when fighting the gun.

Thus nothing can seem more simple and expeditious than the hand-winch gear for running the guns into the exact position for loading—an operation which has almost invariably to be performed, owing to the impossibility of adjusting the compressor to such nicety as to permit the gun to recoil exactly to the loading mark, whatever the motion of the ship—but in actual practice the case is far different. No sooner are the guns discharged than the turret is turned round to load under cover, consequently the men waiting to run in are not able to ship their winch handles until the motion has ceased, and a delay is caused by this of 1 to 1½ minutes before the gun can be sponged. If the ship should be heeling, the guns may have to be dragged up a steep incline, and a further delay is produced.

As there are no means by which the guns can be run out other than the same slow-moving hand gear, the slides of all turret guns are placed at an incline of 3 deg., in order that the guns when tripped on to the rear rollers of the carriage by hydraulic jacks may return by their own weight to the position of firing. But under the condition of the ship heeling 3 deg. or more, the guns would not run out of their own accord, even when tripped on to the rear rollers, and the slow process of running the guns out by hand would have to be resorted to. With a heel of 6 deg. it is doubtful if this could be effected in less than 4 or 5 minutes. By the direct application of hydraulic power to the carriage, the guns could be run in or out under any conditions of heel or motion with perfect safety and great rapidity. The heavy and complicated machinery at present used for running in or out could thus be dispensed with, as well as the hydraulic tripping gear, for the movements of the gun being entirely under control, the carriage could run on permanent rollers or a broad smooth surface be used.

It will thus be seen that if these movements were performed with the very great rapidity and safety which hydraulic power alone can be accomplish, a much quicker fire could be sustained, inasmuch as the gun directly it was fired, and while the turret was being trained out of action, could be immediately run in and the loading commenced, while both the running in and out could be effected with equal rapidity independent of any heel or motion the ship might have, matters which at present seriously impede these movements. An effective fire from the turrets of the Devastation cannot be sustained at a greater speed than one discharged every 7 or 8 minutes, even on an ordinary practice day when the distance and bearing of the target do not materially change. With a quickly-moving target, and under the conditions of action, where rapid motion will be the chief characteristic, it will probably be found impossible to obtain more than one discharge of the turret every 10 minutes. It is true that one gun can be fired at a time, but the fire of the turret, although halved in value, is not thereby in any way expedited, as it is impossible to load one gun while the other is being fired.

The following figures show the actual time in which the loading of the guns was performed on an ordinary practice day.

The whole time of each discharge is not given, as great delay took place in the laying and firing of the guns; but to lay a gun for elevation by the pointer of the wood scale, if any accuracy is sought, takes from 30 seconds to 40 seconds, to which must be added a certain time to align the turret sights, as this alignment is entirely dependent on the motion of the ship. With the 70 or 80-ton gun this time would probably be again increased, perhaps as far as 15 minutes for each discharge.

Number.	Run in to Load after Discharge of Gun.	Sponge.	Load.		Run out and Ease Off Rollers.	Total.
			Powder.	Shot.		
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
1	1 30	1 20	1 20	3 40	0 50	8 40
2	1 30	1 30	3 25	3 20	1 30	11 15
3	1 25	1 0	0 45	2 0	1 0	6 10
4	1 30	0 30	0 50	1 10	2 50	6 50
5	1 20	0 40	1 10	1 20	2 40	7 10
6	1 15	0 50	0 50	1 10	1 0	5 5
7	1 30	1 40	1 0	1 10	1 15	6 35

But in 10 minutes of time two fleets approaching each other for a ram attack, at a combined speed of 20 knots, would pass over no less than 3⅓ sea miles, 6,700 yards, and most naval authorities are agreed that it would be worse than useless to open fire with heavy artillery at a greater distance than 1,500 yards at the very outside. It will be evident, then, that unless the rapidity in working heavy ordnance is very greatly increased, its use will be restricted to a very narrow field indeed.

In another and important particular the working of turret guns as at present fitted is defective. In order to reduce the chances of an enemy's projectiles entering the turret ports, their dimensions have been kept as small as possible. While the inconveniences of horizontal training which result from this having been met by steam rotation, it is sought to give a sufficiency of vertical training by a system of "steps," the gun being raised or lowered from one to the other by hydraulic rams.

But the probable conditions of naval warfare seems to demand not only vertical arcs far greater than those hitherto given, but also a rapidity of movement through those arcs not inferior to that obtained in horizontal training. At present there are generally three "steps," or positions, from which the gun can be fired. When on the bottom step 15 deg. of elevation can, as a rule, be given with but little if any depression; on the centre step about 8 deg. elevation, and 3 deg. to 4 deg. depression; and on the top step 6 deg. elevation and about 5 deg. depression.

In the first place the arrangement of the steps does not give sufficient prominence to a fire which it is believed will have decisive results in future, namely, a plunging fire on an enemy's decks at close quarters. Although a great height of port-sill above the load water-line is given to the latest ships, the range of depression of 5 deg. is quite inadequate in this respect. In France a depressed fire of 20 deg. to 25 deg., and even greater, is now demanded.

Secondly, the system of hydraulic lifting is altogether too slow for the rapid phases of a naval action of the future. If, for instance, in order to open fire when an adversary comes within range the guns are placed on the bottom, or even middle step, it will be impossible to make use of a plunging fire at short distances; for should the slow process of raising the gun be resorted to, it will only be with the imminent danger of finding the artillery useless at the very moment when its services are most urgently required. It is open to doubt whether such a practice is advisable or possible with the great weights with which we shall shortly have to deal. To lift the 35-ton gun from the lowest to the top step cannot be done with the existing hydraulic gear under 4½ minutes to five minutes, and 2½ minutes more are required to lower the ram out of the way. With 80-ton or 100-ton guns, this time would be considerably augmented.

A height of port to give a total vertical arc of training of 15 deg. from one position would be ample for all purposes, and would be but slightly greater than that adopted at present from which 11 deg only can be obtained. With such a height all the requirements of action would be met by keeping the gun in one permanent position for firing from which 7 deg. depression and 8 deg. elevation could be given. It is doubtful under what circumstances the extreme arc of 15 deg. elevation would be used.

Although a comparative facility has already been achieved in horizontal move-

ments of the turret and guns by the application of steam turning gear, the elevating arrangements at present in use are slow and cumbrous, and viewed by the light of the conditions of naval warfare present many serious difficulties. In all broadside guns the sight by which the gun is laid for the object is attached to the gun itself, and thus partakes of every movement of the breech. Owing to the difficulty of the problem it has not as yet been found possible to sight guns mounted in turrets, but a fixed sight is placed on the top of the turret itself and the requisite elevation due for the distance of the object is given to the gun by means of a wooden scale which is set to a certain height, and then made to correspond with other marks on the breech of the gun. The most prominent fault in this method of adjusting turret guns for elevation is that the firer has no control over the actual elevating the gun, and is, moreover, incapable of ascertaining, at the instant of firing, whether his guns are correctly laid for the object or not. A plan for directly meeting these requirements has recently been prorposed by Lieutenant H. H. Grenfell, R. N., and Mr. Edward Newman, Chief Engineer, R.N., and is now under consideration. They propose to directly connect the outside top turret sights to hydraulic elevating gear attached to the breech of the gun in such a manner that the slightest movement of the sight produces an instantaneous and corresponding movement of the breech of the gun in whatever position on the slide the gun may chance to be. The very great advantages of this plan are obvious. The captain of the turret has all the movements of the turret and guns under his entire control, and can keep his guns constantly readjusted for any motion of his own vessel or change of position on the part of the enemy, and can, moreover, discharge his guns while in the act of altering the elevation, should a favorable opportunity suddenly be presented, without danger to the elevating gear. This plan, in conjunction with the those proposed by Mr. Rendel for running in and out and loading, would place all the movements of the turret and guns under the direct control of the firer.

The disasters which arise from errors in horizontal directions are altogether insignificant when compared with those which spring from incorrectness in elevation. It may be said that if the No. 1, who, under the present system, lays the gun, is well trained and trustworthy, few errors will occur; but apart from the intricate method in use, consider the interior of a turret in action and the effect the confusion, noise, smoke, and darkness will have on the accurate adjustment of a small wooden scale on which the whole success of the discharge depends.

The experimental firing of H.M S. Captain at Vigo in 1870, furnishes an instructive lesson on this point; eleven rounds were fired as quickly as possible against a rock at a moderate distance, affording a very large target. The guns were carefully laid for the first broadside, and three out of the four projectiles hit the mark. Of the remaining seven fired in quick succession, only one shot struck this exceptionally large target.

In order to remedy these great defects and to obtain proper accuracy and rapidity in firing from very heavy guns, it is absolutely necessary:

1. That the rear sight of the turret over which the firer takes aim and directs the discharge, should rise and fall with the movement of the breech of the guns, when elevating, and thus insure their being accurately laid at the instant of firing.

2. The firer should himself be able to elevate or depress the guns so as to keep them continuously "covering" a rapidly approaching or departing object, and to fire the instant a favorable opportunity is presented.

Without such a control over the movements of the guns, the results of artillery fire will be but small. Either the fire will be delivered at haphazard, or the guns will be laid for a predetermined distance and the fire reserved until that moment. But, as often happens, the best laid plans may be disconcerted by some trivial circumstance, and smoke, a change of course, or a thousand other accidents may make the fire at that anxiously expected moment impossible. Nine out of ten men would then fire although they saw nothing to aim at. The tenth would endeavor to relay his guns and so probably lose an opportunity of firing at all. On the other hand, the captain of the turret, who has the guns entirely under his independent command by the aid of hydraulic power, calmly and continuously "covers" the approaching foe until the moment when an opportune wave exposes the bow or broadside below the armor plating,

and shot can be instantaneously lodged in a vital point.

This point has as yet received little attention. It has been thought sufficient to provide for the various movements of the gun to and from the position of firing, passing over the question of the actual laying of the gun as comparatively unimportant; yet to those who endeavor to discover what the actual effects of these ponderous weapons will be, facility in loading or running the gun in or out, whether by hand gear, water, or steam, is altogether second in importance to the question of rapid and accurate adjustment and readjustment of the gun when in position for firing. As the question is mainly connected with the technical working of the gun, it may be as well to explain in some detail what actually takes place.

Suppose two turret ships are approaching at the combined high speed of 20 knots. In one the captain of a turret has been directed to open fire at 2,000 yards. His method of preparing his guns under the present arrangements is as follows:

He fixes the turret sight at zero, and names the distance at which the fire will be delivered to the No. 1, who is inside the turret on the platform, "2,000 yards!" Nos. 1 and 2 immediately jump on to the rear part of the carriage; 1 provides the wooden scale, sets it, and holds it against the breech of the gun, 2 attends the elevating gear, and raises or lowers the breech under the direction of 1, until the pointer on the scale is against the mark on the breech of the gun, he then clamps the elevating gear; 1 returns the scale, 2 cocks the gun, and then both step off the slide, and then No. 1 calls out "Ready!" to the captain of the turret.

This process is slow and uncertain. If the turret is full of smoke, or the action be fought at dusk, the marks both on the wooden scale and on the scale on the breech of the gun are so small as to be easily mistaken. It is especially difficult in such cases to see whether the pointer on the wooden scale is opposite the correct mark on the breech, and in the noise and confusion No. 1 may easily fail to distinctly hear the distance called by the captain of the turret, and so set the scale inaccurately. It is not surprising that with so many sources of error such great inaccuracy of firing should have been obtained from the trial in 1870.

But supposing that these various duties have been correctly performed, and the guns consequently accurately laid for the distance of 2,000 yards, let us assume that just previous to reaching that distance a sudden change of course is adopted by either of the two ships, or that smoke from either ship temporarily obscures the other, or that some other of the numerous causes which may occur, prevents the captain of the turret from seeing his object, and consequently firing his guns at that instant. It will be evidently necessary to immediately relay the guns for a new distance, to do which the whole of the operation will have to be gone through over again, with several minor additions, thus:

The captain of the turret calls out the new distance, and sets his sight, the firing gear has to be locked, the tube taken out of the vent, the two numbers then mount on to the carriage, set the scale, relay the gun, reprime it, step off, and finally unlock the firing gear, when the gun is again ready for use. During the whole of this time the gun is out of action, nor is it possible for the captain of the turret to take advantage of a sudden break in the smoke or reappearance of his enemy to discharge his gun; for even if it were left primed it would be impossible to fire without destruction to the two men laying the gun.

In view of these circumstances it is perhaps not too much to say that nine out of ten men would discharge their guns, even though they saw nothing to aim at, sooner than, by embarking on the slow process of relaying, hazard the opportunity of being able to fire at all. With hydraulic elevating gear directly controlled by the captain of the turret, and a slight rising and falling with the movement of the breech, and correctly exhibiting at any moment the actual position of the axis of the gun, all this would be very different. Under these altered conditions it would not be necessary to lay the guns for any prearranged distance, inasmuch as the guns could be kept continuously "covering" the object as it approaches. The captain of the turret keeping his eye fixed along the sights, would hold the firing key in one hand, and with the other constantly adjust the elevation as the enemy gradually approached. The No. 1 placed close to him, or on the quarter platform as most convenient, would effect a corresponding change in the adjustment of the sight due to the enemy's diminishing

distance, while at the same time he keeps the horizontal training of the guns accurately aligned. It is thus seen that without intervention of a single man within the turret, the sights can be continuously readjusted for change of distance, the guns kept constantly covering the object, and discharged with certainty of striking the latter the instant a favorable opportunity is presented.

With very heavy ordnance it is unnecessary to insist on the great importance that each discharge should take effect. The time of reloading, even with mechanical appliances, is necessarily considerable, and the disaster of a lost shot would still be very serious. This power of directly controlling all the movements of the guns on the part of the captain of the turret is imperatively needed, and combined with the application of a movable turret sight would, it may be said, increase fourfold the effect of heavy artillery.

Without some such plan it is not too much to predict that lost shots, confusion, and disaster will be prominent features in the use of the tremendous artillery of the future.

THE REAL REASONS WHY CASTINGS IN IRON ARE ACCURATE COPIES OF THE MOULD.

By ROBERT MALLET, C.E. F.R.S., etc.

From "The Engineer."

The fact that cast iron does take very accurately the form of the mould in which it is cast has been for a length of time attributed to the supposed fact that the metal expands in volume while passing from the liquid to the solid state—a supposition which for more than a century has passed current, though without any sufficient proof. In a paper read before the Royal Society on the 11th of June last, an abstract of which, taken from the "Proceedings" of that society, has appeared in "The Engineer" for the 3d of July last, I have disproved by two independent experimental methods the supposed fact that cast iron does expand in consolidation from fusion. The paper itself will probably be published in full by the Royal Society in the latter part of this year. Meanwhile it may be stated that the methods pursued consisted in, first, the determination of the specific gravity of liquid cast iron, by weighing equal volumes of the liquid metal and of distilled water; the specific gravity of the same cast iron at 60 deg. Fah. being also determined; secondly, by determining the dimensions of a spherical shell of cast iron heated to bright redness, and then filled with liquid cast iron before being heated, when filled, and during the cooling back to the temperature of the atmosphere, when its dimensions were found the same as at the beginning; also by determining the specific gravities of the circumferential and central portions of the ball of cast iron when cold which had filled the shell. The central portions were found much less dense than the circumferential parts, as is well known to be the case in all castings in iron, of whatever size and form; but if the expansion in volume had taken place in the ball cooling by radiation, the central portions must have been found much more dense than the circumferential parts. The agreement of these two independent trains of experiment removes all doubt as to the completeness of the proof that cast iron does not expand in volume in passing from the state of liquid fusion to that of solidity by cooling; and it is therefore certain that the degree of exactness with which cast iron takes the form of the mould into which it is cast is to be otherwise accounted for. It is not necessary I should here advert to the objects in relation to certain lunar volcanic theories with which the above experiments were undertaken, nor to the conditions under which cast iron in the solid state may or may not float on cast iron in fusion; the latter facts, erroneously interpreted, having been, in fact, the foundation upon which the supposed notion of the expansion of cast iron during consolidation has been based. For these and the details of the experiments I must refer to the paper itself. In the mean time some useful deductions of a practical character may be drawn from the facts ascertained. Were it the fact that cast iron in solidifying did expand in volume, a little consideration will show that such expansion would result, not in the casting being an accurate copy of the mould

—whether of green or dry sand, or loam —but must be a distorted copy, the expansion in volume of the metal filling the mould being, in effect, the same as if it were exposed to the hydrostatic pressure of a liquid pumped into it, the yielding to which would be greatest where the walls were least resistant, or where the force to which they are exposed is greatest—namely, where the surface exposed to pressure was the largest. Thus, for example, a flat plate mould from a pattern of equal thickness throughout would when cast be no longer of equal thickness throughout, but have one or both of its broad surfaces forced outwards so as to make the plate thickest towards the central parts, while the edges and corners of the plate which consolidate first would remain nearly unaltered and the metal be found not even completely forced into contact with those parts of the mould; in fact, no form of casting except that of a sphere could under the supposed conditions of expansion in volume remain an undistorted ectype of the pattern, nor could any rigidity in the mould prevent this, the expansive force being by hypothesis irresistible, like that of water freezing into ice.

Cast iron does, however, as is well known, take the form of the mould, as formed of sand or loam by the usual methods of the founders, with great fidelity. We must except, however, the case of chills or massive moulds of cast iron, the liquid metal cast into which is so instantly chilled by contact as not to form a very accurate transcript of the mould. But though cast iron does take a very sharp and accurate transcript of the mould when cast, it does not do so to a greater extent than do several metals to which the supposed property of expanding or consolidation has never been attributed. Thus zinc affords castings of exquisite sharpness from sand moulds, as all those must have remarked who have seen the superb ornamental castings in that metal for architectural and other purposes, which form the staple trade of the great German and Belgian zinc foundries. Lead, also, when carefully preserved, while in fusion, free from oxidation, and cast in slightly-greased moulds so as to reduce any oxide formed therein, affords castings of exquisite sharpness, as may be observed in those of the ancient lead work of the roofs of churches and other buildings of from 200 to 300 years ago in France and Belgium. Gold, silver, copper, and most of their alloys, on the contrary, afford generally more defective castings, and wanting in sharpness. The circumstances upon which these opposite results arise are extremely complicated, and to fully elucidate them would require more space than can be here afforded; they involve conditions mechanical, chemical, and molecular, affecting both the metal cast and the nature of the mould in which it is cast, as well as the relations of these to each other. Among these the following are, perhaps, the most important: First, the density of the metal itself. Whatever be the nature of the metal, it fills the mould when full under a certain hydrostatic pressure due to the height of the liquid column and to the density of the metal, and whatever the metal may be, this is the mechanical force by which it is compelled to follow and fill while liquid the sinuosities of the mould. Let us suppose the liquid head constant, say $2\frac{1}{2}$ ft. or 30 in., we readily see how enormous a difference there yet is in the mould-filling force due to density alone in the five metals, aluminum (which gives extremely defective castings), zinc, cast iron, lead, and gold, their densities being,

	Specific gravity.	lbs. per sq. in. under 30 in. head.
Aluminium	2.560	2.82
Cast iron	7.110	7.856
Zinc	7.146	7.896
Lead	11.360	12.552
Gold	19.340	21.371

Thus, in the last of these metals the hydrostatic pressure tending to fill the mould completely is about seven and a half times greater than in the case of aluminum, and yet both these metals produce inferior castings, while the three intermediate metals afford sharp and good ones. Secondly, the specific capilarity when in fusion and viscosity while passing from the liquid to the solid state. Different metals are liquid in very different degrees while in perfect fusion, and therefore require very different degrees of pressure to force them into angular cavities. Upon this point physicists have as yet given us but little exact information. The greatest diameter of spherical drops capable of being assumed by any metal when taken in connection with its density is, however, a rough measure of the resistance which each presents to being forced into angular cavities of a mould of such material that it is not wetted by the liquid metal; thus fluid solder will readily penetrate between the edges of two clean

tin plates, but will not enter at all if the plates be tarnished or blackened by a candle flame. Drops of mercury cohere at larger diameters than those of liquid lead. So also different metals differ in the range of viscosity through which they pass between their state of most perfect liquidity and that of solidity. Lead and some of its alloys, such as plumbers' solder, pass through a very long range of viscosity; brass and copper do so likewise, though in less degree; cast iron and in general all the metals that crystallize most readily and best, pass through a very brief stage of viscosity. Where the melting point of the metal is a low one, one of the effects of this prolonged viscous stage, during which the metal contracts by loss of heat, is that its withdrawal from the sides of the mould is not compensated by a sufficient continuance of hydrostatic pressure, owing to imperfect liquidity. Cast iron is remarkably free from this objection; its melting point being very high and its range of viscosity small, and confined to a small range of temperature, the metal is maintained, though constantly contracting by loss of temperature, in close contact with the mould by hydrostatic pressure up to within a brief period of its setting. Thirdly, upon the tendency of the metal to oxidate or combine with other elements presented to it in casting, and producing compounds less fusible than the metal itself, greatly depends the perfection or imperfection of the castings produced from it. Fluid zinc oxidates but very slowly up to a temperature somewhat above its melting point, but it oxidates rapidly at and above a bright red heat; hence zinc gives perfect castings; but when it is alloyed with copper, the melting point of the brass is raised to such a point that the zinc oxidates very rapidly, and produces that "tailing" and general scurfiness of surface which is the plague of the brass founder, and the oxide of zinc is not reducible back to metal at the temperature at which brass is cast by any chemical agent capable of being introduced into the substance of the mould. In cast iron, on the other hand, its tendency to oxidate by contact with the atmosphere when in fusion is opposed by the presence of silicon and carbon in the metal itself, and any oxide superficially formed is reduced back to metal with great facility by the hydrogen and carbonic oxide evolved from the moisture and charcoal, or coal dust, or other carbonaceous matter entering into the constituents of the mould. Gold is inoxidizable, but possesses a vigorous affinity for sulphur, and it is probable that the film which may be observed upon the surface of molten gold in casting, and which produces "tailiness" in the ingot or bar, consists of some sulphur compound taken up from the gases from the fuel employed for fusing it. Copper also casts badly, as when in fusion it is constantly either taking up carbon or oxygen as the heat of the furnace is either a reducing or an oxidating one, and the great cleanness of castings produced from phosphorized copper arises from the presence of the small amount of that element precluding it from taking up carbon, on the one hand, and shielding it from oxidation on the other. Fourthly, a high melting point and a high specific heat are favorable to the production of perfect castings, as prolonging the time during which *cæteris paribus* the metal filling the mould is subjected to its own hydrostatic pressure, thus more completely forcing it into sinuosities and expelling air bubbles or other gaseous matters. If the fusing point be very low, as in the case of lead or tin, the viscous point is so rapidly reached by the loss to the mould of the small amount of heat present in the metal that there is but little chance of air bubbles or particles of unreduced oxide being previously forced out. Fifth, the absolute amount of contraction of any metal between the temperature at which it is poured and that of the atmosphere, forms also an element in the perfect correspondence of the casting to the form of the mould in which it was cast. On comparing this rough sketch of some of the principal conditions upon which the degree of perfection of castings in various metals depends, it will be obvious that among all the metals commonly used for castings in the arts, cast iron occupies an extremely favorable position; its density is sufficient to press it when liquid effectively into the mould, its capillarity is not very great, its range of viscosity is small, and it possesses the paramount advantage that whatever oxide may be formed in the casting processes is precluded from becoming diffused throughout the mass by the silicon and carbon present, and that any oxide formed on the surfaces in contact with the mould is instantly again reduced by the hydrogen and carbonic oxide evolved from the mould itself.

In these conditions, indeed, cast iron

may be said to stand unrivalled among metals in the perfection of the castings made from it, and they are quite sufficient to account for that perfection without calling in the now disproved supposition that it expands like ice at the moment of consolidation. The experimental determination of the specific gravity of liquid cast iron adverted to at the beginning of this paper affords us the means—and for the first time—of determining the total dilatation in volume as well as the linear dilatation of cast iron of the quality experimented upon, vis, the fine-grained, bright gray tough cast iron employed by the mechanical engineers. As the specific gravities of this iron when cold and when melted were 7.170 and 6.650, so that the unit in volume when cold being taken as 1000, was increased to 1078.2 at the temperature somewhat above the melting point at which the iron was poured; the total dilatation in volume being thus 0.0782, and this divided by three—*i.e.*, neglecting all but the first term of the series—gives for the total linear dilatation 0.02606, which, taking the whole range of temperature between 60 deg. and 2,400 deg., and if we assume the dilatation uniform throughout the range, gives a coefficient of dilatation of 0.0000.1086 for 1 deg. Fah. This, however, it is not quite correct, as the rate of dilatation increases rapidly within a few degrees of the melting point. The dilatation found as above is also in excess of that due to the precise range between 60 deg. and the melting point of cast iron, the higher temperature in my experiment being somewhat above the melting point, exceeding it by probably about 200 deg. Fah. My direct object being simply to prove that melted cast iron is not denser—as has been stated—than the same cast iron in the solid state, and not that of ascertaining the exact dilatation due to the precise range between 60 deg. Fah. and the melting point; we are enabled, however, incidentally to deduce the latter with approximate accuracy. I must reserve however, for a future communication some further remarks upon this part of the subject, as also upon the interesting phenomena of the movements observable in large masses of liquid iron, as in the largest crane ladles, which have been erroneously appealed to as affording proof that liquid cast iron is denser as its temperature is higher.

AMERICAN ROLLING MILLS.*

From "Engineering."

The object of this paper is to describe the general arrangement of American steel rail mills of recent type, and some of the more important details of their machinery and practice rather than to bring forward any remarkable novelty. The character of mill structures in the Northern States is largely affected by meteorological conditions. A series of small-span roofs covering a continuous area is impracticable; heavy snows would drift into the valleys, and by alternate freezing and thawing, fill them with a dangerous weight of ice. There may be transepts with diagonal valleys and lean-to roofs like those of aisles, bu the succession of slopes should be uninterrupted from ridge to eaves. These conditions require trusses of long span, but not necessarily of greater cost, as intermediate columns and their foundations are avoided. The absence of columns also facilitates the arrangement of machinery. The extreme variations in temperature require a mere shed in summer, and a close building in winter. These conditions are best met by setting the roof on piers, rather than on a continuous wall. The openings are stopped above by windows, and below by doors or by light panels, removable in summer. For ventilation, a number of light chimneys or lanterns of large diameter are found better and far cheaper than a continuous lantern-roof. The mill shown in the diagram on the wall is part of the Edgar Thomson Steel Works near Pittsburg, now nearly completed. It consists of iron trusses, 20 ft. apart, covered with sheet iron, and standing on iron columns 25 ft. high. The main building is 100 ft. by 380 ft., and will be lengthened 80 ft. to accommodate four more re-heating furnaces. This mill is specially arranged to bloom 2-rail or 3-rail ingots, and to roll these blooms into rails, at the rate of 200 tons per day. It is also adapted to rolling heavy merchant steel up to 60 ft.

* A paper read by Mr. A. S. Holley, of Brooklyn, N. Y., before the Iron and Steel Institute at Barrow, England.

lengths. The 23-in. 3-high rail train is divided into three instead of two stands of rolls, in order to be strong enough for heavy sections. The additional lateral movement of the rail on the hooks thus made necessary causes no delay in the long run. Space is left at the end of the train for two stands of merchant roughing and finishing rolls, which may obviously be changed as often as required, without interrupting the continuous working of the rail train. This arrangement renders it practicable to fill small orders for exceptional patterns of rails, and for high-priced merchant work, by executing them in connection with rails, at about the cost of standard rails. By means of a movable saw-carriage the same driving apparatus which draws the rail to the saws also places the carriage in position to receive the bar from either stand of finishing rolls. Two of the carrying rollers behind the train are driven from the saw-engine, and deliver the rail upon the saw-carriage. The rail is usually drawn upon the hot straightening plate by power, thus employing the minimum of labor. It will be observed, that while both in front and in rear of the finishing rolls there is room to handle pieces 60 ft. or more in length, the floor space is otherwise occupied around the roughing rolls, where shorter pieces are handled; and generally that no floor space is wasted, while there is ample room for all the operations. The space between the furnaces and the hot-bed is no greater than would be required for 30 ft. rails. Ordinary lengths are cut by double saws for fast working; 60-ft. lengths are cut, one end at a time, by a swinging saw, in order to avoid moving the bar laterally, which would require a saw-carriage 60 ft. long, and the same additional length of building. The 30-in. 3-high blooming train is so placed as to occupy room in the body of the mill otherwise not used, and is so set with reference to the 3-ton hammer, that the blooms are cut in three and chipped, on their way to their reheating furnaces. The hot straightening plate is placed between two hot-beds, instead of at the end of one, in order to better accommodate two cold straightening presses. As there is not sufficient room across a mill otherwise wide enough, for a hot-bed on which 200 tons of rails per day can be conveniently handled, the necessary addition is made, and at the same time a 60-ft. hot-bed and straightening plate are provided for long lengths, simply by placing two 30-ft. plates and their hot-beds end to end. The finishing machinery is arranged chiefly with reference to economy of labor in moving the rails, but also with regard to economy of room, as it must all be under roof. The rails pass but a few feet from the hot-beds to the cold straightening presses, and thence by an equally short route to the cold beds. The punching machines and drilling machines are so arranged that they can all work at a time on either long or short bars, and can thus finish all the product of the trains. The rails lie always longitudinally with the building, and pass straight out at its end, the only lateral movement being across one of the short hot-beds and cold-beds. The finishing tools are in this case driven by a single engine and overhead shafting, although attaching a small engine to each press and punch is a more common practice. Changing rolls is done by means of a portable crane, which ordinarily stands behind the pinions out of the way. Fixed cranes are commonly used for this purpose, and in some heavy beam and merchant mills, where numerous changes are required, hydraulic cranes, like those in Bessemer works, have been adopted. Placing the reheating furnaces across the building in two rows, as shown, occupies less floor space and is more convenient, considering distance from the rolls, and the working of the double ingot furnaces, than placing them parallel with the building.

The arrangement once so common of furnaces along one side of the building and trains end to end in the middle, both lying lengthwise, is in the newer mills replaced by the arrangement here shown, viz.: trains lying transversely—furnaces at one end, and finishing tools at the other; and it is indispensable for conveniently working long bars. Gas reheating furnaces are exclusively employed in this mill, and in the last two steel mills started in America, as well as in several new iron rail and merchant mills; gas furnaces are being gradually introduced in the best old mills, and it is probable that few American works, save those erected under very exceptional conditions, will in the future embody the old and wasteful system of burning solid fuel in individual furnaces. The Siemens system is of course the most common, being the most highly developed, and it is, without exception, as far as the author is aware, working well, with anthracite culm, and with

every variety of bituminous and semi-bituminous coals.

The Frank system of continuous regeneration, as improved by Mr. Blair, in his open-hearth steel manufacture at Pittsburg, and the Ponsard system, as improved by the Messrs. Sellars, in their puddling and reheating furnaces at Edgemore, are likely to be extensively introduced. For re-heating ingots, a double flat-bottomed furnace is employed, because it is more economical, both as regards construction and floor-space, than two single furnaces of equal capacity, and because ingots, especially when charged hot from the moulds, do not require a heat which produces a troublesome amount of cinder. The bloom furnaces, however, are made single, because they require a sloping bottom and a slag tap in the rear; but chiefly because it is impracticable to secure the uniform high heats necessary, while constantly charging into and drawing from a large double furnace. The ingot furnaces are 20 ft. by 11½ ft. on the working bed; the bloom furnaces are 20 ft. by 6⅔ ft. The ingot charging and drawing apparatus involves the minimum of labor and of cost. A charge of 14 in. ingots, weighing about a ton each, is laid, in the adjacent Bessemer works, upon a railway car. When the ingots are crystallized, but still red hot, the car is drawn to the reheating furnace by a small locomotive. A workman then thrusts a long peel, made of gas pipe, through a notch in the car, under the ingot, until a stop on the peel comes against the rear of the ingot; he then passes a chain fixed to a hydraulic piston, around a sheave which lies on a beam in front of the furnace, and slips it over a V in the end of the peel. Water then being admitted to the hydraulic piston, the peel slides smoothly into the furnace, carrying the ingot with it; turning the peel to one side, by means of its handles, rolls the ingot off. Thus, in four or five minutes, two men and a boy can charge a Bessemer heat of hot ingots. The drawing is done by throwing a hook over the ingot, and passing the chain the other way around the sheave. The ingot slides out upon a hand-bogie, which is readily guided by one man, down a slightly inclined floor to the blooming mill. Here the power feeding-tables, patented by Mr. Geo. Fritz, pull it off the bogie and pass it alternately backwards and forwards through the mill, turning it over as required. Two men and a boy, by means of these tables, roll an ingot weighing a ton, from 14 in. square down to 7 in. square, by sixteen or eighteen passes, in from 3½ to 4 minutes. The most improved features of American roll-trains, for both heavy and light work, are illustrated by the wall diagrams of a 14½ in. bar train, constructed by Mr. John Fritz, at the Bethlehem Iron Works. First, like all American 3-high mills, it has grooved top and bottom rolls, instead of grooved bottom and middle rolls, thus greatly economizing in length of rolls, and preventing the necessity of turning the bar over after each pass. The grooves open alternately upward and downward, and hence the fin that was formed in the top of the groove, on the lower pass is smoothed down by the solid bottom of the groove on the upper pass. Secondly, the grooves are opened and closed while the rolls are running. This may be done by hand, as required, or rapidly after each pass, by the power of the engine. In this way, the bar may be worked over and over in the same grooves, instead of requiring a separate groove for each pass. Rectangular bars, and many such shapes as beams and angles, are thus worked, in many of their passes, in the same time as by fixed rolls, and with much less total length of rolls than is required by the ordinary 3-high or 2-high mills. This is especially convenient for odd sizes. The bolsters of the middle roll are fixed solidly upon shoulders in the housings by bolts in the heavy mills, and by struts (to facilitate changing rolls) in the lighter mills. The top and bottom rolls are simultaneously raised or lowered by the four housing screws, and these are all revolved together, by means of the vertical shaft, the horizontal shaft that connects them and the horizontal hand-wheel shaft and the attached gearing. The upper counter-shaft, which is continuously driven from the mill engine, is made to turn the hand-wheel shaft (which is constantly coupled to the screws) in either direction, by means of belts and a friction clutch. Thus the four screws may be simultaneously revolved either way, and the grooves opened or closed either by the friction clutch or by the hand-wheel. The rolls are counterbalanced so as to reduce the wear on the screws to the minimum, and in such a manner that the whole apparatus hangs conveniently in the pit between the foundations. The housing screws

are fitted with telescopic sheaths, so as to prevent the entrance of dirt, and are oiled by means of a central vertical oil-hole and radial holes leading from it to the exterior of the screw at various points. Housings with solid tops being stronger and more durable than those with movable caps, roll changing is facilitated by making the solid housings so high that when the distance-piece under the screw and the middle roll struts are removed, the bolsters of the top roll can be raised enough to permit the roll to be lifted and swung out. The other rollls are then removed in like manner. Driven feed-rollers are employed both in front and in rear of the rolls, in all mills for heavy work. The first blooming train, in which the rolls were adjusted by power derived from the engine, was erected by the author, at Troy, in 1870, and has been almost constantly running on 12in. and 14in. ingots. In this mill, the middle roll is shifted after each pass, the top and bottom rolls being fixed. The blooming trains at the Cambria and the Bethlehem works, also all the new rail and merchant trains at Bethlehem, and the trains in the Phœnix Iron Company's new mill, and in the Otis Iron and Steel Works, are so constructed; and these features seem likely to be embodied in first-class mills generally in America. In the more recent American mills, roll trains are machine-fitted on all their bearing surface (excepting only the couplings) like steam-engine work, and with the same accuracy; and this, to a great extent, accounts for their large and constant production. The working details of rail mills of this kind are as follows:—Ingot heating is not divided into "rounds;" ingots are charged a Bessemer heat at a time, hot from the moulds, into whichever part of a furnace has most room for them, and the hottest ingots are drawn as fast as required for rolling. There may sometimes be 30 or 40 ingots in the two furnaces at a time. Blooming trains are ordinarily worked up to the capacity of a pair of 5-ton vessels, averaging 150 tons per 24 hours; the Cambria train with two such furnaces has heated and rolled 2-rail ingots at the rate of 300 tons per day. The output, with 3-rail ingots, is about one-fourth greater. The time of rolling a 14in. ingot to a 7in. bloom in sixteen to eighteen passes is from $3\frac{1}{2}$ to 4 minutes. The speed of the train is from forty to forty-five revolutions per minute. The engine, directly connected, is 36in. by 4ft. or its equivalent, carrying steam at 70 lb., and having a 40-ton fly-wheel. The blooms are cut while red-hot into three single rail blooms, either by a heavy shears or under a 3-ton hammer. Chipping, when it is required, is so thoroughly done hot under this hammer that no cold chipping is required. Blooms are often taken hot to the reheating furnaces, but this practice is not as yet general. As most American works have but one pair of 5-ton converters each, and make but 150 tons per day, the rail mills are kept full by rolling steel rails for two or three weeks, and then iron rails for one or two weeks. The regular capacity of the average American 3-high train may be put down at 200 tons per 24 hours; of 60 lb. to 65 lb. rails 30ft. long, although most of the mills have too few re-heating furnaces for so large a product. The Scranton Mill for some time averaged 440 iron rails in one turn, out of eleven ordinary re-heating furnaces, or at the rate of some 225 tons per day. The Superior Mill at Pittsburgh, and the Danville Mill have averaged 360 iron rails per turnout of ten and twelve furnaces respectively. The Cambria Mill and the Troy Mill have frequently made 330 to 340 steel rails per turnout of nine furnaces, which is 180 to 190 tons per day, or from 1,000 to 1,040 tons per week of eleven turns, or five and a half days. A $6\frac{1}{2}$in. to 7in. bloom is rolled into a 60lb. to 65lb. rail in thirteen to fifteen passes; the rolling occupies $1\frac{1}{2}$ to $1\frac{3}{4}$ minutes. The speed of 21in. to 24in. trains is from seventy to eighty revolutions per minute. The engine—direct—is, for steel, the equivalent of 46in. to 4ft., carrying steam at 70lb., and having a 56-ton fly-wheel. The fuel employed in gas furnaces does not exceed 400 lb. per ton of product for each reheat; the steam coal varies greatly with the character of engines, and averages some 600lb. per ton of rails for all rolling mill purposes. The greatest economy of the gas furnace lies in its saving of oxidation. Careful experiments at the Union Iron Works, Pittsburg, show its saving to be 5 per cent in heating iron beam piles, as compared with the coal furnace. A year's practice at the Washburn and Moen Manufacturing Company's Works at Worcester, gave $2\frac{53}{100}$ per cent. waste on $1\frac{1}{4}$in. iron wire billets, against an average of 7 per cent. with the coal furnace; and at the same works a week's run has been made with $1\frac{34}{100}$ per cent. oxidation. The saving of steel is, of course, less than that of iron, because the

temperatures are lower. The future improvements most required would appear to be labor-saving machines to handle the work at the rail rolls. A better rail straightening machine is also very much needed. The limit of production for a single train seems to have been practically reached at 200 tons, or over four miles of bars per day; improved quality and machine-handling are now the problems that first require solution.

In the discussion which followed,

Mr. Edward Williams said there was nothing like the amount of work said to be done in America had yet been done in this country. He did not see why the quantities mentioned by Mr. Holley should not be produced; and he thought what had been done on one side of the Atlantic would probably be done on the other. He should like to ask Mr. Holley whether it had ever occurred to steel rail makers in America to roll rails in the form of a tire, and so save crops. It seemed to him that this was possible, and that it would not be difficult to get such exactness in the weight of the moulds as to bring the circle almost exactly to the size required. To get an open circle and straighten out the rail afterwards would be a simple operation; and he had thought for a long time that in this direction there is a possible economy of a very important kind. It was said that there was a continual stream of ingots going into the reheating furnace, and that they were not charged in rounds, as the custom was in this country; but he presumed that this only applied to first heating, and not to re-heating. He thought that to keep a constant stream of ingots going into the furnace, and another stream running out, if they only wanted heat enough for a bloom or hammering ingots might do well enough, but they could not adopt that system with reheating furnaces where they had to get ingots up to a rolling heat. Mr. Holley told them that the future improvements most required were not labor-saving machines, but the work of rolling rails. He was not unmindful of the cost of the operations as now carried on, and he believed it was quite possible to economize very much; but at the same time he thought there was an economy—a more pressing kind than either of these—namely, the economy that would result from dealing with the fluid pig as it came from the blast furnace, instead of casting it into pigs and carrying it through the needlessly costly and tedious process of remelting. He had been forced into the consideration of this matter by the necessities of the steel works they had at Manchester, where they had been making a good deal of steel at no profit at all for a long time back. With a view to reversing the state of things, he had been going into the elements of cost in the hope of getting rid of some of them, and he found that the cost of bringing back again into fluid form the stream of metal that was originally fluid in the blast furnace was something tremendous. Given any particular day, and there might be seen at the furnaces at Witton Park little streams of fluid pig iron running down a channel into pig beds. A week afterwards the same metal is fluid again, and running down a little sand trough, no better, but rather worse, and less in quantity than it was originally, while 20s. per ton or more has been expended needlessly on the metal between the times. He had come to the conclusion that this of itself is a sufficient reason why the manufacture of steel rails in the neighborhood of Manchester, or anywhere else where there is a large carriage to pay, was not so profitable as it ought to be, and that with very simple appliances and some little attention, it would be quite possible to get the iron from the blast furnances taken at once to the converters and turned out in the shape of Bessemer steel ingots. The coke and ore put into the blast furnace to-day should be steel rails to-morrow, thus effecting a great economy without any counterbalancing objection that he could see; and he was of opinion that this system would very shortly have to come into operation. In point of fact his own company—Bolckow, Vaughan & Co.—had decided to make the attempt, and before long they would either have the thing in successful operation or they should have failed; but he hoped the former. He should like if Mr. Holley would kindly say what had been done in America in the way of blooming steel ingots in four rolls. They had been using at Manchester blooming rolls on the system established by Mr. Chas. Wild, and they were working successfully. He thought that all the advantages and all the reasons educed from their experience were in favor of treating iron in that way; and he thought there was no valid reason why a sufficient num-

ber of rolls, the one before the other, should not be set down, so that the steel ingot might be converted into a bloom by passing from one end to the other, and thus avoid all the trouble they now had with working carriages, reversing, and all that sort of thing. The cost of a blooming machine would not be great, and the rolls would be small short strong things, and not very expensive. Mr. Holley pointed out that by the system adopted in American rolling mills by lowering the rolls they might work a pair in the same groove several times without changing the rolls. That could not, however, apply to a flange rail, or any rail requiring side work; it could only be by passing from one groove into the other. The rolls might be brought together or taken apart very easily, no doubt; but how any work could be put upon the flanges of, say a quarter rail, he failed to see. They might have some mode of doing it not generally known in this country, and he was sure they would be glad if Mr. Holley would explain it to them. He rather envied the mill that could make 1060 tons of rails per week. They had never yet come up to that; but probably they would get a little more energetic, and come up to it by and by.

Sir James Ramsden said that the proposal to run fluid iron into the Bessemer converter from the blast furnace had been under the consideration of the Barrow Company for some time. They tried some experiments in this direction, and came to the conclusion that they were very doubtful, and that they could not produce the same quality of steel, or the quality necessary to satisfy the market at the time. In making the best quality of steel rails, gentlemen will be aware that it is necessary to have certain mixtures of iron; and the iron they run to day as pig iron, if used in the converter tomorrow, would not make the same quality of steel as if it lay for three or four weeks in the pig yard. With reference to the rolling of rails in a circular form and then sawing them through so as to save the waste of crop ends, the Barrow company had also the question under their consideration and decided it to a certian extent. They did now roll hoops of a certain diameter, and there was a large hoop being rolled at the mill on the previous day intended to be used for a certain purpose; but they had come to the conclusion that the best mode of reducing waste was that of rolling long lengths, and they now rolled three rails for two crop ends. The same subject had engaged the attention of Sir Joseph Whitworth, who proposed to make plates by rolling them in large pieces, and then sawing them through. They should be glad if Mr. Williams could show them that he can use the fluid pig iron directly in the Bessemer converter. There would be an enormous saving in the direct process, not only so far as the process itself was concerned, but also in several matters of detail and in the cost of plant.

Mr. Schneider said with reference to the idea proposed by Mr. Williams, that there was one most fatal objection to it, and that was that it was utterly impossible, while the pig iron was in the furnace, to know what its quality was. The whole reputation of the Barrow Steel Works was based on the uniform quality of the steel which they produced. They have had the whole of one cast from the same quality of pig iron; and if they were to run the molten metal direct from the furnace into the converter, they should have accidents with steel rails in the same way as they had with iron rails. The real secret of making good steel lay in this, they must have a pile of pigs brought out cast by cast, placed in a long row and showing uniformity of quality by having every single pig tested before it was put into that row, by breaking it, and seeing what its quality really was, then by taking a uniform depth of pigs along the whole length of 100 yards, so that they had the same quality all through the average of a week, as nearly as it was possible to get it, until they reached the end of the pile. There was a certain amount of sand clinging to the pig which the action of the atmosphere removed, but they could not otherwise describe how it was possible to get better results from pigs exposed to the atmosphere. But the real point to which he wished to direct their attention was this, that they could not secure uniformity unless they cast the iron in the form of pigs and then distributed it, so as to get thousands of tons of the same uniform quality. By this means they could secure uniform results, and defy all the railway inspectors in the world.

Mr. Williams said that Mr. Schneider's was a good old orthodox faith, having only this blemish, that it was not true. It was the old faith which they all held and implicitly believed in, but a good many of them, himself among the number, had been

giving it up bit by bit, until as a matter of fact, it was now pretty well nigh all gone. First of all as to this question of quality, there was no simpler method of maintaining quality than that of using a mixture. If a man making steel would but come to the resolution that he would make it of, say ten or a dozen different qualities of iron, that should all be the best of their sort, and bought subject to being the best of their sort, it was clear that he need take no more trouble for himself, and need waste no discussion upon it. It cannot go wrong. This mixture system would stand in the place of management, and if they laid down as a rule that Bessemer works or foundries were to be managed upon this happy-go-lucky principle, of course the best system was that of mixtures. But it was possible to work with only one kind of iron, which must, however, be the right one, and the man dealing with it must know that it is the right one, and must take care that he is using and making the right kind of material. There was no difficulty in knowing what the iron was before it came out of the furnace. You knew as well what it was when running out, as you knew how many fingers were on their hands. He had been for three years making steel from one kind of iron from one furnace, without any difficulty; and not one out of every thousand tons of pig was so doubtfnl that they did not let it go into the converter like the rest; and they believed that at Gorton they made the best steel in England; at any rate they found no difficulty. They had inspectors and other gentlemen of the most particular kind going on testing and testing until further testing was absurd, and their rails were beyond all question as good as could be wished. That they would never have an unfortunate rail that might break, it would be absurd to say, for it would be impossible to prevent that by any expenditure. That, however, was not the average rail. The worst rail was the one that did not come to pieces in course of rolling, but which, if it had been a degree worse, could not have held together; this was the rail that gave the trouble; and no amount of money they could spend could do any more than reduce the number of such accidental incorrigibles He believed it was a real fact that iron did get better by being in stock. He did not know how it was, but he found that iron as a rule not very good if put into stock for some time was less bad when it came out again. This was a matter that some chemists ought to be able to explain, but which he was not. With regard to the subject of crop ends, a great economy had been effected; and it was no doubt a great advantage in that direction to have two crop ends only to three rails; but if the tire system would answer, they would have no crops at all; and if there was no counterbalancing disadvantage, it would be better even than the excellent system of rolling they had seen that day at Barrow Works.

Mr. W. Richards, of Ebbw Vale, said that the making of ingots from the blast furnace direct had gone far beyond the region of experiment. In the south of France it was being done regularly, and they had also done it at Ebbw Vale. They had two blast furnaces built opposite their Bessemer works, and they got two tons of fluid iron out of one furnace, and 2½ tons from the other, and carried it direct to the Bessemer converter. The iron they got was so uniform that there was not the slightest difficulty in making ingots of a fine quality. The steel turned out of these works was well known and bore a high character for excellence of quality. The process was started about three years ago, and was being worked continuously day and night. At the Seraing Works, in Belgium, they were so satisfied that this could be done, that they were putting up a plant in front of their furnaces, and they are sure of successful results. He thought a great deal of credit was due to the American gentlemen for the immense turnout of ingots they showed. They turned out 125 tons per day—he supposed of twenty-four hours—from a pair of five-ton converters. He did not think that in England they were doing anything like this; but they came nearer to America in the rolling of rails than in the making of ingots. With one pair of engines they turned out at his works a thousand tons of ingots and rolled them into rails in one week.

Mr. Thomas Claridge remarked that at the Chillington Works in South Staffordshire, running iron out of the blast furnace direct had been done for more than twenty years.

Mr. Snelus said there could be no difficulty in running iron direct from the blast furnace to the converter. The thing was to ascertain the reasons why this process had failed before, or the conditions necessary to make it successful. If the blast

furnace was working with a gray cinder, the iron would run out gray; if they put in a good cinder they would have iron free from sulphur; but that iron might come out with 2 per cent. of silica, or only 1 per cent., and on the other hand it might come out with 5 per cent. of silica. Those of them who were accustomed to the Bessemer process knew that if the silica was below 2½ per cent. they got a skull. If it was as much as 5 per cent., it would blow so hot that the bottom would come to grief in one or two heats. They must therefore insure regularity in the silica, if they would get their furnace to work properly. If there was a black cinder in the furnace the iron was not likely to be suitable for the Bessemer process under any circumstances; but if there was a good gray cinder they might take it for granted that the iron would make good steel. What they wanted to do was to equalize the silica in the metal if they found that it was free from sulphur. He had advocated this plan for a long time, but it had been ridiculed, and they were rather conservative in his part of the world. He saw no difficulty in taking two blast furnaces, and not only running the iron into the converters direct, but also insuring regularity in the mixture. Most chemists could tell how much silica there was. If the iron coming out of the two blast furnaces should by any accident be too silicious it could be toned down; but the first essential was to get the metal sufficiently silicious; and to do that it should be run into a separate vessel as in America, and then run into a ladle, which is balanced, from which 1200 lbs. of steel can be run into the converter. If they had an intermediate vessel between the blast furnace and the converter, and found the amount of silica in the iron before it was used, they would have no difficulty in keeping it regulated, and they would find it easy to keep it right in the blast furnace. If they could ensure 2½ per cent of silica in the metal, the metal would be better and not worse, for being run direct from the blast furnace. They would get a better rail by working at a low percentage of silica; but they would be liable to get a skull, and the silica remaining behind would make a brittle rail. They started, of course, from the beginning, and assumed that the metal contained no phosphorus. With respect to the improvement of the pig iron by standing, he did not think there was any doubt that it was due to the removal of the sand, and it would be more evident even in the puddling furnace than in the converter, because it ran away with the fettling, prevents it from being as effectual as it should be, and so wastes the metal.

Mr. Josiah T. Smith said they were now discussing what they might as well leave alone, because they would have all the facts before them in a very short time at the Gorton Works; they were going to remove the Bessemer plant to beside the blast furnaces, and it would be better then to hear the result than to speculate upon it now. He saw no reason whatever why the Bessemer process should not be conducted successfully by running the iron direct from the blast furnace to the converters, provided they were careful in the selection of their ores, and exercised due care in the filling and working of the furnace; but he was bound to say that at the present time he did not see how that care was to be obtained. Given that they had the care and the proper material in the furnace, it was quite clear to his mind that no improvement took place in the actual remelting of the pig in the cupola; in fact, he should rather say the reverse. But with their present practice they knew that they had irregularities, and that they did not always use the same class of ores; and it was impossible, he thought, to sufficiently distinguish those classes to make an absolutely regular mixture. Their practice at Barrow was to have long lines of broken pig iron, so arranged that in no one cast in the converter did they use more than 3 cwt. to 4 cwt. of any particular cast from any particular blast furnace in the same day. They would be exceedingly glad if his friend, Mr. Williams, would help them out of this difficulty. If they were able to do it at Manchester they would no doubt be able to do it at Barrow. But he did not see how they should be able to do it unless they had a marvellous improvement in both their workmen and themselves, or unless they imported some talent from Middlesbrough. It struck him, from the observations made by Mr. Williams, that he must have had considerable experience of bad steel. In the early days of the Barrow Works they had those difficulties to deal with, but they did not see them now, simply because they adopted this peculiar method of mixing the

pig iron before putting it into the converter. He had heard Mr. Holley's paper with great interest, and it made him somewhat ashamed of the production they obtained in their steel works.

Mr. Whitwell said it was no doubt an important matter if they could in America obtain from a five-ton converter from one-half to three-fourths more than they were getting in England, and he wished Mr. Holley to tell them, whatever his opinion was, the increased output of the American converters. He had heard it said outside that room that something depended upon the fitting on of the tuyeres. No doubt one great reason why the Americans were excelling steel makers in England was because they had greatly improved upon the original Bessemer plant arrangements. He thought there was a considerable difficulty about the proposal of Mr. Williams to roll rails in tires. There was no doubt that one of the reasons of the good results obtained by Mr. Williams was because he had b en exceedingly careful in the mixture of his ores.

The President said he should like to know the extent of the difference between burning the coal in an ordinary furnace and burning it in a producer for the Siemens furnace?

Mr. Williams said he should be glad if Mr. Holley could say whether there was a possibility of rolling rails tire fashion, to be straightened out at the end of the operation without reheating?

Mr. Snelus said that the West Cumberland Hematite Iron Company had some of the bottoms Mr. Holley had described, and they would be seen by the institute on the following day.

Mr. Holley said with regard to the economy of Siemens' gas furnace, they were using between 350 lb. and 400 lb. of coal for heating ingots, and about the same for reheating, and in the ordinary furnace from 800 lbs. to 1000 lbs., but they made no steam in the gas furnace. The economy of oxidation was very great. A large production of rails was economical, up to say 150 to 175 tons per day. Several spurts had been made in America, and as many as fifty heats obtained in the twenty-four hours, but beyond that point it was not economical.

Mr. Williams: With a single converter?

Mr. Holley: With one pair. The stream of ingots going into the furnace applied only to the ingots and not to the blooms. They had to be charged in rounds. The ingots heated themselves. The gas furnace did not heat them much; it simply protected them from radiation.

Mr. Williams: Then it cools them?

Mr. Holley: Possibly, to a certain extent.

Mr. Williams: The inside gets cooler?

Mr. Holley: The use of blooming rolls before one another had never been attempted in America. They considered that it would be more complex, and that the radiation would be greater than by their present system of automatic tables.

The President said there could be no doubt that in America they were doing great things in the manufacture of Bessemer steel, and their friends were not averse to tell them, not only what they had done, but also how they had done it. He thought if any one was entitled to the thanks of the meeting, it was the gentleman who had just read the last paper.

THE MANUFACTURE OF CAOUTCHOUC AND ITS INDUSTRIAL USES.*

By EUGENE PAVOUX.

From "Journal of the Society of Arts."

The multifarious uses of india-rubber, and the numerous industries in which it is employed, are such as to give an interest to the consideration of the properties of this material and of the means employed to give it the appearance and the forms under which it is rendered useful.

Its principal quality is its elasticity in an ordinary temperature. This special quality, to which it owes its repute, disappears almost entirely under a temperature approaching to that of melting ice, and only reappears when the india-rubber is subjected to a heat of from 30 deg. to 40 deg. (Cent.), when it again becomes supple. It softens in proportion as the temperature rises, becomes viscous, and ends

* Translated from "La Revue des Mines" for the English edition of that work.

by taking the consistency of treacle. This sensibility to the influence of the temperature must have prevented its being used in industrial pursuits, if means had not been found of neutralizing it by a special manufacturing operation. Above 200 deg. it is decomposed, and passes off in a volatile form.

Its density varies between 0.925 and 0.950.

According to Faraday, it is composed of 87.2 of carbon and 12.8 of hydrogen.

India-rubber is a sap which flows from various sorts of trees which grow in abundance in the regions near to the equator, notably the *Ficus elastica*, the *Siphonia cahucha*, etc. Its qualities are distinguished by the places where it is grown, and sometimes, though rarely, by some external characteristic. The terms most frequently used in the manufacture are: Para, Madagascar, Carthagena, Guyaquil, Borneo, West India, Assam, etc.

It is obtained as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of india-rubber), is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay made in the shape of pears are plunged into the liquid, and afterwards passed over a fire made of the branches of trees, in order that the layer of india-rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The balls are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure.

Sometimes a thin board is used as a nucleus, on which the sap is deposited and agglomerated; in this case, the mass of india-rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest india-rubbers are those which are gathered in this way; such as Para and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter.

When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption. When they are very thin they are rolled up like a skein of thread, and the appearance of the india-rubber in balls serves to remind one of a clue of worsted.

In these different states india-rubber comes to Europe. It is indispensable to rid it of every kind of detritus, sand, wood, pebbles, bark, etc., which have become mixed with the gum while running from the tree. This is the object of the first process in the manufacture. The raw material, after been softened by immersion in a large tub of hot water, is cut up with a saw into cubic pieces of about an inch and a-half, then flattened between two cylinders, placed horizontally, the distance between which is regulated at will by set screws. These cylinders are of different velocities; it follows, therefore, that, independently of the pressure which the india-rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and under the continuous action of a stream of water, they are easily carried off. Under this process, which is repeated eight or ten times, every time bringing the two cylinders nearer together, all the impurities vanish, and the rubber assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

It is important that the material should be kneaded, in order to bring together in a single piece the scattered elements of the sheet, and impart to it perfect homogeneity. This is done by means of a kneader called a "devil," which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp pointed teeth disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute, carries along with it the grained sheet of which I have spoken, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it towards them. There results from this a perfect process of trituration, which forms the sheet of rubber into a

compact mass, all the parts of which are thoroughly mixed.

In order that this operation may be effected under proper conditions, it is necessary that the roll of caoutchouc which has to be put into the cylinder should be a little wider than the cylinder itself, in order that it may press against the sides, and, consequently, be regularly drawn in by the motion of the shaft. This proceeding lasts, on an average, a couple of hours; the longer it is continued, the less time is required for the process which has to follow, by reason of the thorough homogeneity into which the material has been brought.

The devil, as it is called, is usually formed with a double casing, which is heated by means of a steam jet.

I have been induced to abolish this, because I find that the heat developed by the work itself is sufficient to facilitate the kneading of the material, while if it is increased by that arising from the steam, the temperature is such as to cause the rubber to become soft and viscous, and this deteriorates its quality and interferes with the following operations.

On leaving the devil, the material passes to the compressing cylinders, which are placed in couples on a horizontal plane, and may be brought to any distance from each other by means of screws worked by a crank placed within the reach of the workman.

These cylinders are hollow, and are heated internally with steam by a pipe running through a packed box. Two pipes running into one serve to discharge the steam, the ingress and egress of which are regulated, according to the necessities of the work, by taps. The rubber is thus thoroughly compressed until it presents the aspect of a rolled-up sheet, of firm texture, close, and exceedingly smooth. This gives the finish to the preceding operations.

Pure india-rubber is only used for special purposes. The requirements of industry demand various qualities of products, possessing properties suitable to the different uses to which they are to be applied; it is the mixture of blocks of compressed rubber with foreign matters in certain proportions which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances, which is regular and uniform throughout; it is also during this operation that the coloring matter is added, which gives to india-rubber its various shades of gray, black, red, etc., in which it so frequently appears. It is in the form of powder that all these matters are mixed with it. At every passage between the cylinders a portion of it escapes, and falls on a slightly inclined table, which is gathered up by the workman and thrown again into the mass, which, becoming wider by the pressure, is rolled up by the workman as it issues from the cylinders, between which he puts it in afterwards lengthwise. It is, therefore, rolled in every possible way, which tends to give to the texture a greater degree of homogeneity.

The india-rubber paste obtained by this process is afterwards worked up either by rolling or moulding.

In the first case sheets are made of any length and thickness that may be required, while in the second it is cast in any mould the manufacturer may desire.

As regards the rolling, the paste is made to pass between the two cylinders of a calender, by which it is spread out into a sheet of the same dimensions as the cylinders; these sheets may be made to any length, of course, by feeding the calender continually with one block of material after the other. The adhesive tendency of india-rubber is so strong that when the finished sheet has to be wound on to a roller, it can only be done by the interposition of a piece of cloth, which serves to separate the different windings of the sheet. It is then placed on a table and unrolled, in order to be worked up into the form and dimensions required. The same calender serves for coating cloth, which is used for many purposes, among others, for making tubes and straps; the paste, which passes through the cylinders at the same time as the cloth, is spread upon it in a layer, the thickness of which is regulated by the distance, and the tenacity with which it sticks is in proportion to its adhesive qualities.

Certain pieces are suitable for special forms, which they can only be made to take by moulding. In order to manufacture these, the india-rubber paste is put into a mould, which is filled more or less exactly. The exposure of this mould to a temperature varying between 125 deg. and 150 deg. causes the material to expand and penetrate into every part of the mould, and to take the exact form that is wanted. If a hollow article is required, a little water

is introduced, which, being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

There is one remark which it is important to make: it is that the paste adheres easily by simple contact, as long as the material has not undergone the process of vulcanization. The shape then (with the exception of the cutting of certain objects from sheets) should always be given previous to vulcanizing, which is the last process of manufacture.

Raw india-rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of the cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, which is most sensitive to the variations of heat, has the effect of preventing those grave inconveniences arising out of it, and of making india-rubber a substance that can be utilized under any conceivable circumstances. That is the object attained by vulcanization.

The agent employed for vulcanizing is sulphur. Its action on india rubber is analogous to that with which it acts on fatty substances which, when mixed with it in the proportion of one to five, and heated by a temperature of about 200 deg., produce a substance offering a good deal of resistance, and presenting almost the aspect of of india-rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with the heat; it preserves its elasticity, resists acids, and can no longer be made either to dissolve or to adhere.

The incorporation of sulphur is effected either in the solid state or in a state of fusion, according to the nature of the articles that have to be vulcanized. The first method, which is the most in use, consists in mixing flowers of sulphur with the rubber at the same time as the other matters which are added in rolling; it thus becomes uniformly mixed with the mass, but as the reaction to which it must give rise can only be produced at a high temperature, it does not so far modify the properties of the india-rubber paste, which still continues adhesive. The article which is being made is put into a boiler made of sheet iron, capable of supporting a pressure equal to from four to five atmospheres, and closed by a bolted lid; a jet of steam is let in, the tension being measured by a steam gauge, and the length of time during which the operation continues varies according to the number of pieces, but it is estimated at a couple of hours on an average. The necessary temperature is about 150 deg. When it is required to put several objects one on the top of the other, they are sprinkled all over with silicate of magnesia to prevent them from adhering to their supports.

The articles manufactured in moulds with an open surface are vulcanized in presses composed of two hollow, horizontal plates, the uppermost of which is movable, and worked by screws which allow it to work up and down. The moulds are placed between these two plates, and in this manner the paste is compressed. The necessary temperature is produced by the steam which circulates in them from pipes placed at one of the extremities, and passing at the other end through outlet pipes.

I have had fixed up in my manufactory a large press of this kind, by which I am enabled to vulcanize sheets, with great economy of time; the plates are about 7 ft. long by 4 ft. wide; their internal surface being carefully planed and dressed they give to the sheets a glossy appearance, with remarkable uniformity of character.

To produce vulcanization by the liquid method, the sulphur is put, in a state of fusion, into large boilers, underneath which are large fire-places; the articles already made are plunged into these boilers, care being taken to keep them covered with the liquid by means of weights. This precaution is indispensable, in consequence of the difference in density of the sulphur and the rubber. The absorption of the metalloid takes place, and is gradually completed until the combination is effected, which takes from two to three hours. Experience will be the best guide as to the time when the operation has been accomplished. Care must be taken that it is not continued too long, because in this case the rubber becomes hard and loses its elasticity. As soon as the articles are taken from the boiler, they should be plunged into cold water; this causes the layer of sulphur de-

posited on the surface to crack, after which it is easily removed by scraping.

It is as well to remark that only small objects admit of this method of vulcanization; those of larger size must undergo the first process.

There are also other methods of vulcanization which, although less applicable to industrial products, nevertheless deserve to be mentioned. Chloride of sulphur mixed with sulphuret of carbon, in the proportion of one to fifty, will produce this result. When immersed in this compound, the rubber becomes impregnated in a few minutes, after which it is plunged into a reservoir of cold water: the object of this is to neutralize the effect which a too prolonged immersion would have upon the surface, which would be to vulcanize it too much. During the immersion, the mixture penetrates into the centre of the mass. It is only articles that are not very thick that can be subjected to this process.

It is exactly the same as regards the process which consists in the use of all alkaline sulphurets; the operation lasts about four hours. In consequence of the restricted application of this method, it may be regarded as more theoretical than practical.

After vulcanization, the surface of the rubber sometimes presents slight efflorescences of sulphur; these are easily removed by washing with an alkaline solution.

To dissolve india-rubber no better agent can be employed than sulphuret of carbon, to which must be added 5 per cent. of anhydrous alcohol; a product is thus formed which, when subjected to evaporation leaves a residuum of rubber possessing all its primitive qualities. It may also be dissolved by any of the essential oils, but the material which results from their evaporation is oily and viscous, so that their use has been entirely abandoned.

Before proceeding to treat of the industrial uses of india-rubber, it will be interesting to say a few words respecting indurated rubber, which constitutes a special branch of manufacture; independent of its restricted application to great industrial purposes, it is applied to the manufacture of a large number of objects of all shapes and dimensions, adapted to ordinary daily wants. The manufacture of indurated rubber may be disposed of in two words. The quantity of sulphur which is mixed with the paste is large, and amounts, according to circumstances, to from 35 to 40 per cent., and the vulcanization is prolonged beyond the ordinary limits, the maximum being from six to seven hours. For great thicknesses, a longer time may be necessary, but this is an exception. The operation is a very delicate one, and demands a great deal of care to prevent the article being burnt, as it in that case would become worthless.

Indurated india-rubber is worked with the file, the saw, and the lathe, exactly like metals and other hard substances.

The applications of india-rubber to industrial purposes are exceedingly numerous, and are increasing daily. "Its elasticity, its tenacity, added to which, the property it possesses of being completely homogeneous and impermeable, recommend it for a vast number of uses in which it would be difficult to find a substitute."

The various kinds of joints which are used for water pipes, gas pipes, and steam pipes may be classed in several categories, and india-rubber is used in all of them. The flat washers for flange joints are made in various qualities of material, but most frequently by means of one or several cloths dipped in the paste, and intended to prevent the lateral extension which would take place in pressing the surfaces together as well as by the heat, in the case of joints with steam at high pressure; the number of cloths depends upon the thickness of the washer. Instead of being parallel at the surface, the cloths are frequently disposed concentrically, and are placed at a distance from each other of from two to three millimetres. The same result may be obtained with felted india-rubber, that is to say, mixed with fibrous matter, such as woollen or cotton waste, etc., which by their resistance admit of greater tenacity, and cause the lateral extension to be less felt.

In laying the flange pipes, it often happens that, through the negligence of the workman, the centre of the washer does not coincide with the axis of the pipe, and causes a projection in the inside. When this defect presents itself at the lower part of a steam pipe, it prevents the waste water from running off; it is better, therefore, to adopt the system in which the washer is kept in its place by a flange at one of the ends of the pipe; the play left between the two pipes admits of expansion, without causing any danger.

The washers with circular section which are used for joining the pipes are especially employed in the ingenious system of which M. Leon Somzé is the inventor. The washer is introduced by being rolled into the annular space between the two ends, called male and female, of the jointing pipes, and is kept by the conical form of the male end in a perfect state of compression.

In making Delperdanges' joints it is necessary to use a ring forming a band, which, placed on the flanges, which are close to each other, of two pipes, is compressed and kept in its place by an iron bridle, terminated with two claws, which are pressed and brought together by a bolt. A copper sheet keeps the rubber against the pipe, where the claws are. This system has been at work in the water distribution of Lille and Valenciennes. Lastly, certain joints are made by means of a cord, either round or square, made of india-rubber alone or of felted rubber, which is placed in a groove in the two surfaces which have to be joined. The compression of this cord hermetically closes the two ends of the pipes.

India-rubber is also largely employed in transport. On the railways, the buffers are furnished with a series of washers of rectangular shape about 2 m. in thickness, separated from each other by sheet-iron plates, which allow each washer to be compressed singly, so that every advantage is derived from the characteristic property of the material. To allow the passage of the buffer rod, these washers are pierced in the centre with a hole, the diameter of which is larger than that of the plates, in order that the depression of the washer may not drive back the rubber against the rod. For the same reason, the sheet-iron plates are of larger diameter to prevent the rubber from being pressed back beyond their outer edge.

In the construction of passenger carriages, arched pieces are used, which, being fixed in the inside of the wainscoting of the doors, receive the shock of the glass windows as they are lowered, and preserve them from the breakage to which they would be exposed without this precaution.

In tramways, the springs are replaced by buffers, taking the form of two truncated cones, united by their bases; these buffers, placed between the box and the axles, weaken, by their elasticity, the jolting of the cars, and render the motion exceedingly smooth and gentle. The tenacity, strength, and duration of the springs depend upon the proportion of foreign matter which the material contains; there ought to be only a small proportion, but a certain quantity is essential, in order to give them the requisite body and solidity. The use of these springs in the wagons belonging to mines and quarries would, undoubtedly, diminish the deterioration in the rolling stock by preventing the violent shocks which are frequently caused by the dilapidation of the roads.

India-rubber is also used for the outer rim of wheels for vehicles used in railway stations, large manufactories, entrepots, etc. In this case the metallic rim of the wheel takes the shape of a groove, in which the elastic band is embedded; the diameter of the latter is ordinarily calculated at four-fifths of that of the wheel.

Road locomotives appear to have acquired an increase of tractive power by the application of similar bandages. There is no vehicle, even down to the velocipede, which does not make use of this material, endowed as it is with so many precious qualities.

It enters largely into the construction of machines, and especially of pumps. The valves vary in form as well as in thickness; some are round, others are square or rectangular. The seat on which they rest has several apertures, they are thus supported otherwise than on their edges, which preserves them against the pressure. The metallic breastwork which forms the seat ought to present no projecting edge, which would enter into the material, and cause speedy deterioration. These valves are, for the most part, made of simple india-rubber, but sometimes cloth is put between to give them greater tenacity. The special circumstances under which they have to be employed will guide the maker in the selection.

Certain valves are composed of a simple metallic sphere, covered with india-rubber, which, being raised by the liquid, falls down again as the piston descends, on the orifice it is intended to close. In order that these valves may retain sufficient suppleness to admit of their hermetically closing the orifice, it is better that they should consist of a hollow india-rubber sphere, filled almost entirely with small shot.

An ingenious application of india rubber is that which has been made by M. Field,

in respect to a valve composed of two india-rubber discs slightly conical, and placed face to face. These discs are flat and pierced with a hole in the centre, but they are compressed, and made to assume a conical shape by metallic pieces in the interior. Their external edges are in contact with each other, and maintained thus by the pressure which is exercised on their outer faces. The principal merit of these valves is their perfect resistance to the strongest pressure; in fact, their action being exerted in every part at the same time, the lips of the valve are forced against each other, with an energy which is greatest when the pressure is strongest. Messrs. Whitley, of Leeds, have applied this valve to all kinds of pumps, for pumping either cold or warm water or other liquids at pressures rising as high as ten and even thirteen atmospheres.

The Perreaux valve is exclusively composed of india-rubber. The side gets gradually thinner until it comes to the sharp edge, which is split, and opens out a little under the pressure of the liquid; it closes again as soon as the piston begins to descend.

As regards pumps which are intended to pump acids, an india-rubber bucket is used, in which the rod of the piston is placed; these pieces are moulded.

Hydraulic press rings made of india-rubber replace advantageously those covered with leather, which are high in price. These rings are moulded in exactly the form required, and they are much more flexible than leather ones, even of the very best quality.

India-rubber pipes, by reason of the multiplicity of their uses, and the diversity of their composition, form an important branch of manufacture. Those that are used for gas, acids, etc., and have to bear only a feeble pressure, are made of pure rubber by simply rolling a strip of paste round a mandrel; the soldering is easily effected by contact merely, and is consolidated by the pressure of two small blades, worked by hand. To prevent the paste from adhering to the mandrel, care is taken to dust it first with powdered talc. Sometimes several strips are placed on top of the other, the number being determined by the thickness of the pipe which is being made.

When the tubes are intended to be subjected to a certain pressure, they are consolidated by the insertion of one or more layers of cloth, the cohesion of which prevents the swelling of the pipe, the wearing away of the sides, or their rupture under extraordinary pressure. These pipes are generally formed as follows:—A round of india-rubber on the mandrel forms the first tube, over which a strip of cloth is rolled, done over with india-rubber by a calender; a fresh round of pure paste is followed by a second covering of cloth, and the operation is repeated according to the number of folds the pipe is intended to have: this number of folds depends on the diameter, and increases generally with it. The outer envelope is india-rubber. By increasing the rounds of cloth, we obtain pipes capable of resisting the strongest pressure.

When a liquid has to be pumped up, it is necessary to guard against the crushing of the pipe, which the atmospheric pressure would inevitably cause. For this purpose a spiral is used, made of galvanized iron or copper, which is either simply placed in the interior of the tube, or imbedded in the thick part of the rubber. Generally the outer part of the tube is formed of coarse cloth, which serves as a protecting envelope, as these pipes are nearly always intended to be trailed on the ground; they are much used for engines and pumping engines.

All these kinds of tubes can only be vulcanized after they have been finished. They are placed on a vehicle which runs on rails, and run into a boiler 20 yards long, specially prepared for them.

I manufacture a particular kind of pipe, for which I have taken out a patent. It is made of tanned hemp, with an inside casing of india-rubber, and can be advantageously applied to a great number of uses. Being tanned, it is enabled to resist moisture, which has not the slightest effect upon it. It is much lighter than leather, consequently, in case of fire, a man can carry a much greater length, and can mount a ladder with it much more easily. The application of india-rubber sheets to the interior of these tubes prevents the infiltration of water into the pores of the tissue; it also prevents any loss of liquid, and protects them from injury. The resistance is very considerable; a diameter of $1\frac{3}{4}$ in. will bear a pressure of fifteen atmospheres, and one of $\frac{3}{4}$ in. will bear twice the amount of pressure. They are used for fire engines, for brewery funnels, water pipes, steam pipes, etc.

The ropes used for packing, which are

made of cloth, done over with india-rubber, are made without core, that is to say, without any inner nucleus in pure rubber; they are generally used concurrently with hemp for furnishing stuffing boxes, and with the best results; the flexibility of the hemp admits of the expansion of the rubber, and this, in its turn, corrects the want of compactness presented by textile fabrics.

Straps merit special notice. They are composed of a certain number of folds of cloth done over with rubber, alternating with layers of pure rubber. The number of folds, and, consequently, the thickness of the strap, is in proportion to its width: for this reason, when the width is above 10 centimetres, there are at least three folds; above 15 centimetres, four folds; and above 25 centimetres they have from five to seven folds. They are made of all lengths in a single piece, and are joined exactly like those in leather. They work as well in water as in places heated to a high temperature. Their use is becoming very general, for besides being less costly than those in leather, they adhere much better. It is important that the several cloths of which they are made should not slip one over the other, and they should be made to adhere firmly by the intermediate layers of rubber. This object is attained by their being vulcanized in the press.

India-rubber has been used for some time in covering metal rollers employed for sizing and finishing cloth; wooden rollers are replaced by metal ones, which prevent the necessity for using paper or cotton for stuffing the inside of the dressing cylinder; it also does away with the use of linen or woollen cloth for the external covering of the roller, one or more sheets of india-rubber being now used instead. Manufacturers find great advantage in this. The size, whether colored or not, adheres sufficiently to the rubber to admit of either threads or tissues being well sized without any absorption of the material by the rubber; the size, therefore, as well as the coloring matter can be taken off the roller by simply washing it with water, which permits the immediate use of the same apparatus for sizing in the other colors. The india-rubber covering, by adhering thoroughly to the metal, and having none of those protuberances caused by the crossing of linen or woollen covers, presents a perfectly smooth and regular surface, and gives greater uniformity to the sizing.

The thickness of the covering varies from 12 to 15 millimetres, according to the diameter of the cylinder. To have it in good order, the surface of the cylinder should be perfectly smooth.

Billiard makers secure great elasticity for their side cushions by using india-rubber, to which they give various shapes at discretion. The material used for this purpose ought to have rather greater density than the raw rubber.

The other industrial uses to which it is applied are innumerable: I need only mention the buckets and funnels used for acids, plugs with and without holes, rings and flanges for the joints of washing machines, rollers for twisting frames, sets of pulleys for ribbon saws, guide straps and aprons for paper-making machines, joints for filter presses used in sugar manufactories, moulds for hat manufacturers, aprons for sugar works, etc., etc.

As regards the application of indurated rubber, we may mention the rollers for spinning frames, made in two parts of different composition and color, the vulcanization of which is effected gradually, by means of a slow and progressive elevation of temperature, and lasts about four hours.

In telegraphy, insulating bells are used, suspended on hooks of galvanized iron. The outer surface is polished all over, and presents a thickness of $2\frac{1}{2}$ millimetres, so as to cut off the electric current.

If I were to point out all the applications of india-rubber to surgery and ordinary uses, I should become involved in an endless nomenclature utterly at variance with the object of this brief memoir.

PUZZOLANA, NATURAL AND ARTIFICIAL.

From "The Builder."

One of the most valuable occupations of men of science in France, is that of examining and re-examining from time to time the various substances in use in the arts, analyzing their composition, testing their positive value, and explaining the *rationale*

of their manufacture or preparation. This habit is the dire enemy of the rule of thumb, and the results being published in scientific journals of repute, are open to all the world. In this way, within a few years, most of the materials used in building, stone, marble, lime, etc., have been examined and reported on by educated and practical engineers, and others, with great advantages to those occupied in construction.

A careful essay on Puzzolana, natural and artificial, is now before us, and we proceed to give a *resumé* of the principal points for the benefit of our readers.

The puzzolanas are argillaceous compounds, which, mixed with quicklime, are rendered hydraulic, and improve the qualities of hydraulic limes. The name comes from that of the town Puzzuoli, near Naples, where the Romans obtained it in ancient times. They well knew its value, but did not understand its nature. Little was really known of it scientifically, till the end of the last century, when Vicat determined the value of the various elements of wh ch it was composed.

The natural Puzzolanas may be divided into two classes, the volcanic, and those which are composed of natural substances not volcanic, such as siliciferous and amphibolic rocks, argillaceous sand ,and chalk containing gelatinous or semi-gelatinous silica.

The volcanic pozzolana is lava, or the produce of eruptions, the composition of which varies according to its age, the depth of the deposit beneath the soil, and the nature of the substances with which it is mixed. The essential elements are alumina, silica, peroxide of iron, and sometimes manganese, lime, soda, potash, and slight traces of other substances. It is found near extinct and active volcanoes, in the form of powder mixed with coarser substances, filled with cavities, having the appearance and porosity of pumice-stone. It is of various tints,— white, gray, yellow, brown, violet, and that of Rome is of the color of wine lees. The best kinds are found in Italy, and the principal shipping ports are Leghorn and Cività-Vecchia. The price is about 28s. to 29s. the cubic metre. It is also found in several of the departments of France, and there are large deposits in the island of Guadaloupe, to be obtained at a third of the above price. Great quantities have also been found in the island of Santorin, in Greece, richer in silica than that of Italy or Germany (Audernach), and its employment has given excellent results. The price on the spot is almost nominal.

M. L'Esler gives the following analysis of the Greek puzzolana :—

Silica	68.50
Alumina	13.31
Oxide of iron	5.50
" magnesia	0.73
Lime	2.36
Soda	4.71
Potash	3.13
Water	1.45
Chloride of sodium	0.31

The *traus*, or trass, of Holland, and of Audernach and Plaid-, in Germany, when pulverized, forms excellent puzzolana, which has been used in the great works of Holland and on the banks of the Rhine. It is said that the mortar made with it is not affected by sea-water, which, if true, deserves confirmation.

Natural puzzolana contains from 60 to 90 per cent. of clay, and 10 to 40 per cent. of lime.

Vicat analyzed all the principal known kinds of puzzolana, and we have eight results before us, of which we give the first and the last :

Roman Puzzolana.

Mixed sand	5.00
Silica	47.66
Alumina	14.33
Magnesia	3.86
Peroxide of iron	10.33
Lime	7.66
Water	7.03
Alkaline and volatile substances	4.13

Puzzolana of Audernach.

Silica	48.94
Alumina	18.95
Magnesia	2.42
Peroxide of iron	12.34
Lime	5.41
Water, etc.	11.58

In other cases the proportion of mixed sand is much larger, reaching 20 per cent., while in others there is scarcely any pure silica ; the quantity of alumina varies also from 11 to 18 per cent., and the iron from 10 to 34 per cent.

The natural non-volcanic puzzolanas are various. The siliciferous rocks, gaize, or pierre morse,—soft, light stone, found at the base of the chalk formation, and which contains sil ca in the gelatinous or semi-gelatinous form,—have the puzzolanean qualities, but in a weak degree. The following is the analysis of M. Sauvage:—

Silica, soluble in liquid potash	56.00
Chloride sand, very fine	12.00

Quartzose sand	17.00
Clay	7.00
Water	8.00

The amphibolic rocks, or decomposed diorites, found in Lower Brittany, and particularly in Finisterre and Morbihan, have the appearance of coarse clay of a red or dirty white color. Their employment after a slight burning, which improves their qualities, was found tolerably satisfactory by M Avril, Inspector-General of Points et Chaussées, in the constructions connected with the Nantes and Brest canal. They contain 10 per cent. of sand, 38 to 60 per cent of silica, 23 to 29 per cent. of alumina, 10 to 22 per cent. of peroxide of iron, and very small quantities, or none at all, of lime and alkaline substances.

The sand in the vicinity of Brest, which owes its origin to the decomposition of granitic gneiss, is also used for the same purpose, after slight burning. It contains 60 per cent. of silica, 21 per cent. of alumina, 8 per cent. of iron, 6 per cent. of lime and magnesia, and nearly 3 per cent. of soluble matters.

Near Saint Assier and Musudan, in the Dordogne, there are entire hills composed of quartz-sand mixed with clay, known as *arènes*. They contain 4 per cent. of quartz or sand, 38 per cent. of silica, 20 per cent. of alumina, 12 per cent. of peroxide of iron, 8 per cent, of carbonate of lime, and 17 per cent. of water.

Some of these puzzolanas produce mortar which sets after three day's immersion, while others require fifteen days; these are extremes between which lie many intermediary qualities.

M. Vicat thus estimates the relative value of the puzzolanas made from the following clays:—

Pipe-clay and fire-clay produce puzzolana set down at the relative value of 77 to 100, average 90.50 per cent; the average composition of these clays is:—Silica, 58.25; alumina, 28 per cent.; and water 13.75 per cent.

Ochrey clay, value 70; composition on the average,—silica, 59.10; alumina 19, peroxide of iron, 10, water, 12 per cent. These two clays are burnt in the ordinary way; the following are submitted to extra heat.

Marly clay, power as puzzolana, 63; composition—silica, 30 per cent; alumina, 20 per cent.; peroxide of iron, 2 per cent.; carbonate of lime, 38 per cent; water, 10 per cent.

Brick earth, power equal to 45; composition, average—silica, 23.50 per cent.; alumina, 10.50 per cent.; peroxide of iron, 6 per cent; carbonate of lime, 24 per cent.; carbonate of magnesia, 9 per cent.; sand or quartz, 19 per cent. water, 8 per cent.

Among the puzzolanas made from burnt clay most frequently employed in public works of importance, may be mentioned that of Chartres, which has an average density of 1.200 kilogrammes per cubic metre. Mixed with two-thirds of common hydraulic lime, the mortar sets under water in three days. That made at Faquières, in the Marne, has a density of about 1,300 kilogrammes. Two parts of quicklime and one of this puzzolana, form a mortar which sets after forty hours' immersion.

Blue schists calcined, or slaty schist, of which the best deposits are found in the commune of Haineville. in La Manche, have yielded, after having been heated to whiteness, excellent puzzolana.

The employment of the ochreous earths was pointed out by Chaptal in 1797; it may be burnt either with wood or coal, and the two products are not injured in any way by being mixed.

The puzzolanas made from the various clays contain, according to Vicat, from 30 to 66 per cent. of silica, 19 to 32 per cent. of alumina; some contain 1 to 13 per cent. of lime, 4 to 14 per cent. of iron, and some as much as 14 to 30 per cent. of inert matters.

Artificial puzzolana has been made from time immemorial from broken bricks and tiles, but with very variable and generally poor results. It could not be otherwise, for the production of good puzzolana depends upon the fact of the material being burnt only to a certain extent.

Coal cinders, peat, and wood ashes, especially the last, make puzzolana of good quality; they must be sifted with care to rid them of foreign substances, and they should be stored in a dry place and only moved in fine weather.

Forge scoria pulverized and finely sifted has high qualities for producing puzzolana.

The residue from the fabrication of nitric acid with clay and azotate of potash forms the most valuable and energetic puzzolana.

The mortar in which it enters acquires a hardness superior to that of the hardest lias. The cost of the material, however, which is only used in the south of France, prevents its being much employed.

The above is a pretty complete list of the various kinds of puzzolana in use at the present day in public and private works, and in places where materials are dear they are of great service. The complete knowledge of their various qualities can only be obtained by actual experience; generally, however, it may be affirmed that the puzzolanas which are affected by acids are the most effective; but their employment in marine hydraulic works must be avoided, as salt water will completely disintegrate them.

The artificial, like the volcanic, puzzolanas, are the produce of the effect of fire in bodies essentially composed of silica and alumina.

The materials generally employed, then, are clays, the mud of seaports, docks, etc., the sands called arènes, already mentioned, argillaceous schists, ferruginous clay, ochreous earth, broken bricks and tiles, wood ashes, cinders, scoria, the residue of nitric acid, and certain amphibolic rocks in a state of decomposition. The burning is effected in the same way as that of bricks and lime, the material being sometimes formed with lumps, and sometimes burnt in a state of powder or irregular fragments. In the last case, they are treated in reverberatory furnaces. This plan, which was employed by M. Pesot, saves the cost and labor of pulverization after burning, which is always greater than when effected previously.

M. Vicat strongly recommends a system which consists in drying the clays in the sun, or by means of hot air, and then reducing them to powder in a mill, on the principle of those used for coffee and spices, or with stones, and then exposing the powder to sufficient heat to drive off all the moisture which it contains. He employed for this purpose a series of hollow cylinders in cast iron, placed near to each other, in which the powder is introduced, the cylinders being so arranged as to pass successively through a conduit, formed of non-conducting materials, which receives a current of air heated to 600 deg. or 700 deg. centigrade. A slight inclination is given to this conduit, so that the slightest effort is sufficient to cause the cylinders to move through it by merely removing that one at the lower end and placing a fresh one at the other. The powdered clay only partially fills the cylinder, so that it rolls over itself as the latter proceeds, and all the particles come in contact with the hot air. By this means the puzzolana obtained possesses all the qualities of which it is capable. It must be noted, however, that each kind of clay demands a different degree of heat, which can only be settled by practice.

Clay is transformed into puzzolana when it has lost the water it contained, and also the faculty of making a paste with water. M. Vicat designates "normal burning" that which has been conducted under the following conditions:—1. The previous reduction of the substance to be burned to fine powder; 2. The action of fire limited to 600 deg. or 700 deg. centigrade, and maintained till the aluminous hydrosilicate becomes anhydric; 3. The admission of air during the whole operation. "Super-normal burning" he describes as that which, without being carried above 750 deg. centigrade, has been sufficiently prolonged to decompose the carbonate of lime contained in the clay.

The same author, from a large number of experiments and observations, derives the following conclusions:—

1. The rank which a substance holds as a material for puzzolana depends almost precisely on the proportion of argillaceous matter which it contains.

2. Other conditions being equal, that clay is the best which contains the largest proportion of silica, without, however, passing a certain limit, so as not to exclude all the aluminium.

3. Of various puzzolanas of equal proportions and principles, that which has the greatest specific gravity is to be preferred.

4. "Normal burning" develops most fully the qualities of all puzzolanas made from materials free of carbonate of lime, or not containing more than 12 to 15 per cent. of it.

5 In all other cases the "supernormal burning" is more effective.

The methods of burning as well as the qualities of the puzzolana vary *ad infinitum*. General Trussard, who has given great attention to this subject, prefers clays which contain about equal quantities of silica and alumina, and only 0.4 or 0.5 per cent. of carbonate of lime. Pottery clays are often of this character. The General recommends them to be treated in the same manner as bricks, to make them up into lumps, larger or smaller in proportion to the lime they contain, and afterwards to reduce them to very fine powder by means

of silk bolters, as the finer the powder the greater is the effect of the puzzolana.

M. Saint-Léger in his work at Meudon, mixes with the clay a quarter of its volume of quicklime in the form of paste, and he obtains artificial puzzolana far more energetic than the best natural puzzolanas, and which remains unaltered for an indefinite time, an advantage which the hydraulic limes do not possess.

Following the indications above given, excellent puzzolana may be made anywhere, when the composition of the material at hand has been ascertained. M. Berthier furnishes the following ready method of analyzing clays:—"When the clay contains lime the latter is always in the form of carbonate; its presence may therefore be easily ascertained by pouring a few drops of any acid or vinegar on to a piece of the clay in water, when effervescence will take place in proportion to the amount of the lime present. The analysis of calcareous clays is the same as for argillaceous limestone."

LIGHTING RAILWAY CARRIAGES.

From "The Engineer."

Possibly the most imperfect detail in our railway system is the method adopted of lighting the carriages. We do not allude to the windows, although there is plenty of room for improvement even as regards these, but to the provision of artificial light for night travelling. Apparently there is no reason why a railway carriage should not be as well lit as a drawing-room. The space to be lighted is small, and the expense must in any case be very little as compared with that of other items essential to railway transit. But as a matter of fact, even on the best managed railways, the light supplied by the regulation lamp is simply wretched. To read at night is impossible, and the utmost that has been effected is to render darkness visible by the use of a heavy, lumbering, evil-smelling appliance, the cost of which is by no means small, while the waste of material in the shape of oil and wicks which attends its use is absurdly great. The public complain loudly and reasonably. But there is little cause to doubt that the railway companies are perfectly aware of the disadvantages of the existing system—directors constantly travel by rail—and it is not to be disputed that many attempts have been made to provide better lighting apparatus than that with which we are all but too familiar. Many difficulties have stood in the way, however. The great defect of the existing lamp is that oil to be burned properly requires a chimney; but it has been found impossible to use argand lamps in railway carriages. They are exposed to incessant draughts, and the chimneys break continually; and the labor entailed besides, even if the chimneys stood, in keeping them clean, would be inimical to the adoption of the forced draught system of combustion. It does not appear, indeed, that so long as oil is to be used for illumination, anything much better than the existing lamp, or more satisfactory in handling, can be adopted. The obvious way out of the difficulty lies in using gas. How far this is a satisfactory remedy any one in the habit of travelling on our metropolitan railways can judge. The gas is carried under the ordinary pressure in bags on the top of the carriages, and for short runs say four or five miles, the plan answers tolerably well; but air is apt to get in with the gas, and a very small admixture of air will remove a large proportion of the lighting power of the flame. It has been proved that 5 per cent. of air mixed with gas will reduce 16-candle to little over 10 candle power, and this defect is very apparent on the Metropolitan railway; and besides the light is not so steady as could be desired. Imperfect as the application of gas to lighting railway carriages still is as a system, it is still certain that it gives results much better than oil as regards the comfort of passengers. But unfortunately coal gas cannot be used for long runs. To carry a reservoir or gasholder large enough to last for a run to Holyhead from Euston, for example, would be impossible. A large vehicle would be required to convey the gasholder alone. Many attempts have been made therefore to use gas under pressure, so that a large number of cubic feet may be stored in a small space, but hitherto these attempts have all proved abortive, because coal gas when compressed appears to deposit carbon, and loses nearly all its lighting powers;

and, in addition, it is found to be very difficult to keep coal gas at all under pressure, as it leaks slowly through vessels which would be quite air-tight. There is a way out of the trouble, however, and experiments now being tried on the London and North-Western Railway, to which we wish to call attention, have given results so satisfactory that there is reason to hope that gas will supersede oil on our railways as effectually as it has done in our dwelling-houses.

Herr Julius Pintsch, of Berlin, has long been known on the Continent as a maker on a great scale of gas-meters and gas fittings. As far back as 1867 he placed himself in communication with the officials of the Niederschlesisch-Märkische Railway, and proposed a new system of lighting railway carriages with gas. They co-operated cordially with him, and after more than three years of experimenting all difficulties were overcome, and the Pintsch system of lighting has been adopted regularly on the railway in question, and is being rapidly applied on eight other lines, including that from St. Petersburg to Moscow, and the Austrian "Nord-Kaiser Ferdinand." The system consists in fitting each carriage with a reservoir of wrought iron, into which gas is forced to a pressure of about six atmospheres, or 90 lbs. The gas then flows from this reservoir through a very simple and ingenious regulator to a lamp made of cast iron and of the simplest possible construction, which is placed in the roof of each compartment in the ordinary way Now all attempts to use coal gas in this way have been failures, for the reasons already explained; but Herr Pintsch employs oil gas, which is quite unaffected by the pressure when made as he makes it. The oil-making apparatus consists of a double-story retort. The oil, which may be whale oil, dead oil, common blue shale oil, coarse petroleum, fat—in fact, almost any cheap hydrocarbon will do—is introduced in a continuous stream into a tray in the upper retort. Here it becomes partially volatilized, and then circulating through the lower retort the process is complete, and the gas is passed through a short length of pipe provided with a tarwell, and thence to a purifier charged with sawdust and lime, and thence to a gasholder. On the Niederschlesisch-Märkische Railway the cylindrical portions of two old locomotive boilers with flat ends riveted in, are used to hold the gas, which is pumped in by a small compressing engine operating not on the gas directly, but on oil which rises and falls with the pistons in a way which will be readily understood. The gas is pumped into these at a pressure of 90 lbs. At the side of a convenient piece of rail several small stand pipes are erected, which are in communication with the compressed gas reservoirs, and from these, by the aid of a stout india-rubber hose and coupling, the reservoirs under the carriages are filled much as the bags are filled on the Metropolitan Railway. About eight minutes are required to supply a long train with gas. The gas is led to the lamps on the roofs by small pipes $\frac{1}{4}$ in. bore, and the fittings are so contrived that the burner, which is of the batswing type of steatite, is readily turned back out of the basin of the lamp to permit the latter to be cleaned. The glass bowls can be replaced, if broken, in a few minutes. A reflector is placed over each flame, and through this reflector passes a flat chimney, the air for combustion comes down outside this chimney, finding its way in through small perforations, and at the highest speeds no flickering of the flame is perceptible. This lamp is in itself worth the attention of railway companies, even if it were to be used with oil, as it possesses many advantages over the ordinary lumbering contrivance. Before the gas reaches the lamp, however, it has to pass through the regulator, and this is one of the essential features of the whole design. It consists of a small cast-iron box placed under each carriage out of the way. This vessel is divided into two portions by a diaphragm of dressed sheep-skin, which is partially supported by a small lever and spring. The lever acts on a little conical valve, and the moment the pressure becomes too much the diaphragm rises and shuts off the gas. We have seen this regulator tested, and its action, we can say from personal observation, is perfect; and it is found that the gas improves the quality of the leather, being, as it is, free from acids and rather oily in its nature. It is unnecessary here, we think, to enter into farther descriptive details.

As regards the results, it will be asked. first, for how many hours can gas be carried? And secondly, what is the light given? As regards the first point, we may state that a composite carriage has been fitted up on the London and North-Western Railway. This carriage has been run-

ning for some weeks. It carries gas enough in a r ceiver, ma le of wrought iron ⅜ in. thick, 5 ft. 10 in. long, and 1 ft. 4½ in. diameter, at five atmospheres pressure, to run twice to Holyhead and back, sufficient gas being left for a farther run to Chester, if necessary. In other words the carriage carries gas for over 1000 miles. It may be imagined that the gas would waste away, or lose its illuminating power during so long a run, but this is not the case. We found the carriage after two runs to Holyhead and back, and having stood at Euston three days, still carrying pressure of one atmosphere, as tested by a Bourdon gauge, put on for the purpose of ascertaining the pressure. But the point has been set at rest by Herr Gust, of the Niederschlesisch Märkische Railway, who filled a receiver, and left it untouched for eight months, at the end of which time it was found to contain g s under a considerable pressure and of good illuminating power. The apparatus in use at Euston for making the g s is temporary and of the rudest description; two pieces of 3in. wrought iron piping about 4ft. long c nstitute the retorts, which are heated by coke burned in a sheet iron furnace. The purifier is about as big as a hat, and the gas-holder was made by a tinsmith; the oil used is that drained from the carriage-lamp bowls, and is, we need not say, sufficiently filthy stuff; the pumping is done by a couple of men. As regards the second question to which we have referred, we may state that the oil gas is probably of nearly 40-candle power, and the light in the carriage is about 7 to 4 in favor of the gas.

We have spoken thus fully of Herr Pintsch's system, because it appears to have been well and carefully thought out. The labor involved is partly proved by the enormous number of patents which have been taken out from time to time to cover improvements. The use of this system on the Continent is an accomplished fact, and the results obtained on the London and North-Western Railway really appear to leave nothing to be desired but its more extended adoption. Of course, it is quite possible that better systems of lighting may be used, but we venture to think they have to be yet invented. We have said nothing about relative cost, that is a matter of detail little affecting the public, and not possessing scientific interest enough for discussion here; we believe, however, that the expense of the light is found on the Continent to be about 70 per cent. cheaper than oil lamps.

THE COLOSSEUM OF ROME.

From the London "Times."

The excavations in the Colosseum have now reached a certain degree of completion, and far exceed in general interest any of the important works of exploration which, since the commencement of this century, have restored so much of the remains of the ancient city to light. Every Sunday and holiday afternoon numbers of people of all classes flock there to examine, discuss, and gaze in wondering admiration at the gigantic constructions, gradually being disinterred, so colossal in their dimensions as almost to throw into the shade that portion of the edifice which, for the last six centuries, at least, has been looked upon as fully justifying its name of Colossus among buildings.

It is scarcely an exaggeration to say that what is now being revealed excites as much wonder in all who look upon it for the first time as the building in all its integrity did in the Saxon pilgrims when they burst forth with the well-known exclamation recorded by the venerable Bede. But it is no mere massive foundation which has been laid bare; it is no less than 21 ft. of the interior of the edifice itself—buried till now under a mass of accumulation—which has been restored to light, and with it much is made clear that has hitherto puzzled both the learned and unlearned alike. Until now the Colosseum has been an unsolved riddle in many respects. We knew that it was built for the exhibition of wild animals, as a place where they could be shown in numbers to the people, and where they could be hunted and made to fight with each other or with men; that gladiatorial shows on an enormous scale were given here, and that many martyrs testified with their blood on the arena. The ranges of seats rising one above the other could be fully recognized, utterly ruined as they are, and the admirable arrangement of the

eighty different flights of steps, intersecting and yet not interfering with each other as they conducted to the seats, could be perfectly understood. But how were the animals brought into the arena? Where were they kept? What was the stage mechanism of this enormous amphitheatre? These are questions asked by all, but which have never been answered except by imperfect explanations founded on conjecture. We may accept the explanation that the animals were kept in great *vivaria* on the Cœlian and near the Porta Maggiore, but that they were brought thence into the amphitheatre in cages was far from satisfactory.

To test this by one of many records, how, if they were introduced in cages, could 100 lions have bounded together upon the arena with a roar which made the building shake, as we are told by Vopiscus was the case during the games given by the Emperor Probus? And then what confusion there must have been outside, or, rather, how was confusion prevented between the actors and the audience on their way into the building, between, on the one hand, the thousands flocking into the amphitheatre together with the many thousands more who, not fortunate enough to obtain tickets, gathered in the open area around for the excitement of listening to the rousing of the animals, the cries of the victims, and the shouts of the spectators; and, on the other, the bands of gladiators, with all the multitude of men requisite to guard a number of savage beasts maddened by hunger? The edifice was surrounded by a portico divided into eighty arches, every arch, with the exception of two only, forming an entrance to the seats, including the *pulvinaria;* the numbers corresponding to the tickets are still visible on the keystones of those remaining. The two arches, one at each end of the longer axis, were supposed to be the only part reserved for the entrance of the gladiators and the animals; but, with a public entrance through the arch on each side of these, it was difficult to understand how so circumscribed an area—however well it might have been railed off—could have been sufficient for all the work "between the wings," for the entry of the army of men and the hundreds of wild beasts, and the exit of the dead of whichever kind. These are problems which have puzzled all who have considered the subject, however slightly, but which these excavations have now completely solved.

At the beginning of this century extensive excavations were made on the arena, but with no other result than to increase the difficulties they were intended to remove. Immediately beneath the modern surface a network of walls was found intersecting the area in various directions. Some maintained that these were constructions of a late period superimposed upon the arena, while others insisted that they were subterranean, and formed the dens in which the animals were kept and the corridors through which they were introduced upon the level above. A furious controversy was carried on; but, as the construction of the Roman buildings was a subject then but imperfectly understood, no authoritative conclusion was arrived at; and as the place during the rainy seasons got flooded with water, which remaining stagnant and slowly evaporating became a cause of unhealthiness to the city, the excavation was filled in again in 1813, after having remained open for about ten years. Some months ago Signor Rosa determined to make another attempt to clear up the mystery, and now, 21 ft. below what has so long been looked upon by many as the arena, he has discovered its veritable level, paved with *opus spicatum*, or herring-bone work, and leading from it a series of enormous corridors with immense chambers, where the business of the amphitheatre was prepared—the "behind the scenes," in fact. He has gone deeper than the first excavations were carried, and it is now evident that they were confined to the ellipse within the podium.

We must wait until the entire area of the arena is cleared before it can be positively decided whether the constructions superimposed upon it are remains of the work of the Frangipani, who converted the Colosseum into a fortress, or if they were built, as is quite possible, to raise the arena above its original level. In the mean time, however, there can no longer be any doubt that, for whatever purpose they were constructed, they are the work of a very late period, and have nothing whatever to do with the edifice as originally built by the Flavian Emperors, and as it must have remained for a considerable period. We may therefore dismiss them for the present.

It is generally supposed that the low wall at the back of the "stations," which were erected in the middle of the last century,

was the front of the podium; but it is now found that those stations stood on its level, that the wall behind them was the back and not the front, and that a platform 3 metres 70 centimetres in width extends from it to the edge overlooking the arena 7 metres below. From the front of the podium, at about two-thirds down to the level of the arena, a series of gigantic brackets of travertine project at regular intervals, and evidently extend along the entire circuit. On clearing the front of the podium down to the level of the arena, at the end of the larger axis of the ellipse towards the Lateran, three great archways were found, opening under it from the arena, but completely filled with an accumulation of solid clay, such as would be deposited by an inundation of the Tiber. The side archways measure 3 metres, 85 centimetres in width, and that in the centre 2 metres 28 centimetres. Opening the middle archway, it was found to be a corridor extending from the amphitheatre. As the excavators tunnelled along it they disclosed one after the other a series of flat arches, perhaps I should say architraves, massively constructed of great blocks of travertine, and held together by colossal keystones. This corridor, continuing in a straight line, has been cleared to the length of 100 metres without the termination yet being found; but at the distance of 85 metres from the arena, and about 12 beyond the exterior of the edifice, another corridor of the same dimensions branches off from it to the right, in the direction of the caverns on the Cœlian, believed to have been a *vivarium*. Exploration was then commenced through the side archways, and they were also found to be the opening of corridors radiating from that in the middle to the length, however, of only 24 metres, when they turn at right angles, the one to the right, and the other to the left, and communicate with a long corridor between them; the ground-plan being that of a blunt wedge with the end towards the arena, or of a dovetail with the end from it. I may remark here that the floor of the side corridors is on a level with the arena, while that in the centre is about one metre higher.

One great advantage the Government possess in having a man like Signor Rosa at the head of the executional department is, that being an engineer of no inconsiderable skill, he goes to work in a thoroughly scientific manner. Having created a sufficiently large receptacle where water could gather, he lost no time in taking the requisite precautions against the first spell of wet weather inundating the excavation and interrupting his work, to say nothing of its possibly causing malaria. Considering that naval shows having been given in the amphitheatre implied the necessary arrangements not only for flooding the arena, but also for letting off the water afterwards, he commenced excavations still deeper, and soon found a well-built *cloaca*, about 2 metres in height, immediately beneath the long corridor I have mentioned, and a mouth opening with it between the floor of this corridor and that of the arena, with several bars of the metal grating to prevent solid bodies washing down still *in situ*. This *cloaca* has been sufficiently cleared to provide an outlet for any water that might accumulate, and is in itself a solution of the somewhat debated question whether the amphitheatre was used for a *naumachia* or not.

When the side corridors were entirely cleared, a series of circular holes from 17 to 30 centimetres in diameter were found along the central line of each. On examination these proved to be large sockets of solid golden-colored bronze. Each is a block of metal 41 centimetres square, with dovetails projecting on two sides to hold them firm on the blocks of stone into which they are set, the depth of the sockets being from 25 to 30 centimetres, and each having a convex bottom.

Signor Rosa is of opinion that these side corridors were, so to say, the docks for the galleys used in the naval shows, and that the sockets were to hold upright posts to which they could be moored and kept erect till there was sufficient water for them to float. Considering, however, that in each corridor of 24 metres in length there are six of these sockets, at distances apart gradually lessening from 4 metres 80 centimetres at the opening, to 2 metres 50 centimetres at the end, this can scarcely be possible, and I am inclined to think, as the sockets have all the appearance of having been made for pivots to turn in them, that they mark the positions of swing gates, which, when closed, formed so many pens, one behind the other, from which groups of animals could be let loose in succession on the arena. As I have mentioned, these corridors were filled with solid clay, no doubt deposited during inundations of the Tiber,

the water washing back through the *cloacæ*, as it does now when the Pantheon is flooded, and, from these great bronze sockets being *in situ*, and no holes having been made in the walls here, as in the upper part of the building to abstract the metal clamps, it is evident that this portion of the amphitheatre must have become covered with deposit at a comparatively early period, possibly also immediately after an exhibition of animals had been given, and before all the bodies of those slaughtered had been removed, for a number of bones of wild beasts were found in one of the corridors.

Describing the end of the longer axis of the building towards the Lateran, where these discoveries have been made at the east end—it is very nearly—your readers will understand me when I say that the whole of the front of the podium has been cleared as far as the northern end of the lesser axis—that towards the Esquiline. Here, exactly in a line with the axis, another corridor, corresponding in size to those at the east end, opens from the arena. This has not yet been cleared, but an opening has been made outside the building, and it is seen to extend inwards and outwards. There are lateral corridors here, and, as there was no *vivarium* to the north, we may suppose this to have been an entrance for the gladiators and *bestiarii* only, and possibly for the removal of the dead bodies.

Considering the perfectly symmetrical plan upon which the Colosseum was built, we may reasonably infer that on the south side towards the cœlian, another corridor will be found corresponding to that on the north, and at the west end towards the forum three others, or, at any rate, one other, corresponding to those at the east. Your readers will remember that on the side towards the cœlian a passage beneath the modern level was known to exist, and in fact a portion of it has been open from above for many years, but it passes under the fourth arch from the centre towards the east. From its mosaic pavement and the handsome stucco ornaments found on the vaulting it is believed to be the private passage built by Commodus, and in which Quintianus made the attempt to assassinate him. The excavation has not been carried sufficiently far on that side to show if it opens on the arena; but its course is being followed on the outside of the building, and it is seen that, after continuing onwards for a short distance, it turns, nearly at a right angle, towards the east in the direction of the branch which turns to the south from the long corridor running eastward. The direction of these passages would seem to indicate their junction at a point further on, so that together they would lead to and from the *vivarium* on the Cœlian; but as it can scarcely be supposed that the decorated corridor of Commodus led to a menagerie—and, in fact, there is no positive authority for the modern conjecture that one was situated there—it is probable that these corridors led to the Gladiatorial Schools, the *Ludus Matutinus* and *Gallicus*, and the *Spoliarium*, *Laniarium*, and *Armamentarium*, mentioned in the Regionary Catalogues. This, however, in the mean time, is but conjecture, and the object of my letter is to report ascertained facts.

These excavations have established beyond doubt that the arena was not a "movable platform," with dens or receptacles below from which the beasts were introduced upon it; that the constructions below the modern level which led to and seemed to justify this supposition belong to a very late period; that they are superimposed upon the arena, and for whatever purpose they were built they are far too small to have contained the larger animals, even singly; that the arena was a solid floor, and that upon it debouched a number of great corridors, having a series of lateral chambers, sufficiently large to justify the records of the number of animals exhibited together; while the *cloaca* which has been found with a grated opening proves that naval shows were given in the building.

There is no longer any difficulty in understanding all the details connected with the spectacles given in the amphitheatre. The enormous openings yawning upon the arena, give a vivid reality to the descriptions of the scenes once enacted within these walls; but little imagination is now wanted to repeople the ranges of seats with the mighty concourse which once filled them, or to appreciate the intense, the breathless expectation with which, as the boys who scattered the sand left the arena, the 87,000 spectators listened to the echoing roars of the animals and watched the mouths of those weird tunnel-like corridors for the first actors to bound upon the scene.

THE CONDITIONS OF THE MANUFACTURE OF EXTRA-SILICEOUS PIG IRON IN THE BLAST FURNACE.

By M. SAMSON JORDAN.

From the "Universal Review of Mining."

Those engineers who are accustomed to the management of blast furnaces, and to the manufacture of pig iron of a special character and especially those who have had to supply the pig for conversion into steel by the Bessemer process, have been obliged to make themselves acquainted with the conditions under which is produced that class of pig iron denominated "chaud," that is to say, one that contains from 1½ to 2½ per cent. of silicon; some have, indeed, run extra-siliceous pig, containing, for instance, 7 to 8 per cent. of the metalloid. These last-named classes of pig iron have an appearance peculiar to themselves; the brightness of their newly-made fracture increases in proportion to their percentage of silicon; their texture is coarse, but the granules are slightly rounded, without any projecting point; the brightness resembles that of pure silicon; the finger, on being passed over the surface of the fracture, experiences a sensation quite different from the rugose feel of the fracture of gray pig, rich in graphite. Moreover, in the works which produce them, this extra-siliceous iron has obtained the name of "glazed pig" (in France *fontes glacées*).* The following is an analysis of pig iron of this class run from the blast furnaces of Towlaw, near Newcastle:

Carbon	2.39
Silicon	5.73
Sulphur	0.12
Phosphorus	0.13
Titanium	0.02
Nickel and cobalt	0.04
Manganese	1.33
Metallic iron	90.21
	99.97

I have made myself acquainted with the details of the production of extra-siliceous pig at several works, among others that of Heerdt, near Dusseldorf, and the publication of the following details may prove useful:

On the occasion of an accident which necessitated extensive repairs to the tube which led to the blast to the six tuyeres of his blast furnace, M. Butgenbach, the manager of the Heerdt Works, was obliged, in order to keep his furnace in blast, to work for eight days with only three tuyeres and a slight pressure (10 centimetres of mercury, instead of 15 to 18 centimetres as was usual); the temperature of the blast was found to have risen considerably (from 500 deg. to 600 deg.) on account of its diminished quanity and the magnitude of the appliances for heating it. The number of charges was considerably reduced, and, in order to run no risks, so also was the weight of each charge of ore, 1250 kilogrammes (yielding on an average 38 per cent. of metallic iron) being put in with 1,000 kilogrammes of coke and 600 kilogrammes of flux (*castine*).

The following are the proportions of the fusible substance contained in this charge, which went to slag:—

Silica	50	Oxygen	26
Alumina	16		
Lime	33	Oxygen	17.6
Protoxide of manganese	1		
Proportion of the oxygen of the silica to the oxygen of the bases			26 : 17.6

This charge yields a viscous slag, which, when cold, became vitreous and translucid like slags rich in alumina, the color being a bluish opal white.

The corresponding metal was very "lively," and retained a large amount of heat; it ran along the channel formed in the sand in a uniform stream, like molten lead, without the least bubbling, and without scintillations; it filled the moulds exactly without adhering to the sand. When cold, it was very brittle, and had no metallic ring. It was a typical "glazed pig," and its analysis gave:—

Silicon	7.90
Phosphorus	0.72
Carbon	2.60

The corresponding consumption of coke was 2,100 kilogrammes for every 1,000 kilogrammes of pig iron.

In works using aluminous ores, as in those of Aveyron, where Mondalazac ore (which contains 11½ per cent. of alumina with only 10 per cent. of silica and 15 per

* This pig iron has nothing in common with looking-glass pig. (*fonte miroitante*), and it is in error that this equivalent is given for "glazed pig" in certain French works on metallurgy.

cent of lime and magnesia) is made use of, very siliceous pig is, as a rule, turned out, which wastes very much in puddling. Since their blowing in, the blast furnaces have always produced extra-siliceous pig iron which is denominated "flat grained" (*à grain plat*), and which contains 6 and even 7 per cent. of silicon. The production of this pig from a charge of aluminous ore always leads to a large consumption of coke.

At the St. Louis Works, near Marseilles, which generally turns out pure gray pig iron, with slag of nearly the following composition—

Silica	33
Alumina	15
Lime	50
Other substances (magnesia, manganese, &c.)	2

the iron contains, as a rule, only 1 to $1\frac{1}{2}$ per cent. of silicon. In order to obtain very "lively" Bessemer pig, containing about 4 per cent. of silicon, it is necessary to modify the charge so as to obtain—*

Silica	40
Alumina	19
Lime and mangesia	41

Having noted these and other analogous circumstances, I am in a position to state that the following are the conditions in the blast furnace suitable for turning out an extra-siliceous pig iron:—

1. Slow, but very hot blast.
2. Siliceous, but, at the same time, very aluminous charge.

It is necessary that the blast be hot to allow of the union of the silicon with the metal (it is more refractory than the pig simply carburetted); it is necessary that it be slow in order to allow time for the reduction of the silicon in the presence of the carbon and of the iron to take place to a sufficient extent. It is necessary that the charge should be but slightly calcareous in order that the affinity of the lime for the silica should not prevent the reduction of the latter; and, for the same reason, it is necessary that the alumina should be present in sufficient quantity to neutralize still further the basic action of the lime playing the part of an acid, and probably forming one of the aluminates investigated by Berthier.

*The manufacture of a special pig depends almost entirely on the composition given to the slag by the charge, provided that the blast be regular and sufficiently hot.

FORCES DUE TO DIFFERENCE OF TEMPERATURE.

From "Nature."

It has been noticed by several philosophers, and particularly by Mr. Crookes, that, under certain circumstances, hot bodies appear to repel and cold ones to attract other bodies. It is the object in this paper to point out and to describe experiments to prove that these effects are the results of evaporation and condensation; and that they are valuable as evidence of the truth of the kinetic theory of gas, viz., that gas consists of separate molecules moving at great velocities.

The experiments of which the explanation will be given were as follows:

A light stem of glass, with pith-balls on its ends, was suspended by a silk thread in a glass flask, so that the balls were nearly at the same level. Some water was then put in the flask, and boiled until all the air was driven out of the flask, which was then corked and allowed to cool. When cold there was a partial vacuum in it, the gauge showing from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch pressure.

It was now found that when the flame of a lamp was brought near to the flask the pith-ball which was nearest the flame was driven away; and that with a piece of ice the pith was attracted.

This experiment was repeated under a variety of circumstances, in different flasks and with different balances, the stem being sometimes of glass and sometimes of platinum; the results, however, were the same in all cases, except such variations as are about to be described.

The pith-balls were more sensitive to the heat and cold when the flask was cold and the tension within it low, but the effect was perceptible until the gauge showed about an inch, and even after that the ice would attract the ball.

The reason why the repulsion from heat was not apparent at greater tensions was clearly due to the convection currents which the heat generated within the flask. When there was enough vapor, these currents carried the pith with them; they were, in fact, then sufficient to overcome the forces

which otherwise moved the pith. This was shown by the fact that when the bar was not quite level, so that one ball was higher than the other, the currents affected them in different degrees; also that a different effect could be produced by raising or lowering the position of the flame.

The condition of the pith also perceptibly affected the sensitiveness of the balls. When a piece of ice was placed against the side of the glass, the nearest of the pith-balls would be drawn towards the ice, and would eventually stop opposite to it. If allowed to remain in this condition for some time, the vapor would condense on the ball near the ice, while the other ball would become dry (this would be seen to be the case, and was also shown by the tipping of the balance, that ball against the ice gradually getting lower). It was then found when the ice was removed that the dry ball was insensible to the heat, or nearly so, while that ball which had been opposite to the ice was more than ordinarily sensitive.

If the flask were dry and the tension of the vapor reduced with the pump until the gauge showed $\frac{3}{8}$ of an inch, then, although purely steam, the vapor was not in a saturated condition, and the pith-balls which were dry were no longer sensitive to the lamp, although they would still approach the ice.

From these two last facts it appears as though a certain amount of moisture on the balls was necessary to render them sensitive to the heat.

In order that these results might be obtained it was necessary that the vapor should be free from air. If a small quantity of air was present, although not enough to appear in the gauge, the effects rapidly diminished, particularly that of the ice, until the convective currents had it all their own way. This agrees with the fact that the presence of a small quantity of air in steam greatly retards condensation and even evaporation.

With a dry flask and an air-vacuum, neither the lamp nor the ice produced their effects; the convection currents reigned supreme, even when the gauge was as low as $\frac{1}{4}$ inch. Under these circumstances the lamp generally attracted the balls and the ice repelled them, i. e., the currents carried them towards the lamp and from the ice, but by placing the lamp or ice very low the reverse effects could be obtained, which goes to prove that they were the effects of the currents of air.

These experiments appear to show that evaporation from a surface is attended with a force tending to drive the surface back, and condensation with a force tending to draw the surface forward These effects admit of explanation, although not quite as simply as may at first sight appear.

Although there must always be reaction corresponding to the visible motion, whenever vapor is driven off from a surface, this visible motion is too small to account for the forces under consideration. But although it appears to have escaped notice so far, it follows as a direct consequence of the *kinetic* theory of gases that whenever evaporation take place from the surface of a solid body or a liquid, it must be attended with a reactionary force equivalent to an increase of pressure on the surface, which force is quite independent of the perceptible motion of the vapor. Also condensation must be attended with a force equivalent to a diminution of the gaseous pressure over the condensing surface, and likewise independent of the visible motion of the vapor. This may be shown to be the case as follows:—

According to the kinetic theory the molecules which constitute the gas are in rapid motion, and the pressure which the gas exerts against the bounding surface is due to the successive impulses of those molecules, whose course directs them against the surface, from which they rebound with unimpaired velocity. According to this theory, therefore, whenever a molecule of liquid leaves the surface henceforth to become a molecule of gas, it must leave it with a velocity equal to that with which the other particles of gas rebound—that is to say, instead of being just detached and quickly passing off into the gas, it must be shot off with a velocity greater than that of a cannon-ball. Whatever may be the nature of the forces which give it the velocity, and which consume the latent heat in doing so, it is certain, from the principle of conservation of momentum, that they must react on the surface with a force equal to that exerted on the molecule, just as in a gun the pressure of the powder on the breech is the same as on the shot.

The impulse on the surface, from each molecule which is driven off by evaporation must therefore be equal to that caused by the rebound of one of the reflected mole-

cules (supposing all the molecules to be of the same size), that is to say, since the force of rebound will be equal to that of stopping, the impulse from a particle driven off by evaporation will be half the impulse received from the stopping and reflection of a particle of the gas. Thus the effect of evaporation will be to increase the number of impulses on the surface; and, although each of the new impulses will only be half as effective as the ordinary ones, they will add to the pressure.

In the same way, whenever a molecule of gas comes up to a surface and instead of rebounding is caught and retained by the surface, and is thus condensed into a molecule of liquid, the impulse which it will thus impart to the surface will only be one-half as great as if it had rebounded. Hence condensation will reduce the magnitude of some of the impulses, and hence will reduce the pressure on the condensing surface.

This explanation is then put in a mathematical form, and the paper proceeds.

Applying these results to steam, we find that at a temperature of 60 deg. the evaporation of 1 lb. of water from a surface would be sufficient to maintain a force of 65 lbs. for one second.

It is also important to notice that this force will be proportional to the square root of the absolute temperature, and consequently will be approximately constant between temperatures of 32 deg. and 212 deg.

If we take mercury instead of water, we find that the force is only 6 lbs. instead of 65; but the latent heat of mercury is only $\frac{1}{30}$ that of water, so that the same expenditure of heat would maintain nearly three times as great a force.

It seems, therefore, that in this way we can give a satisfactory explanation of the experiments previously described. When the radiated heat from the lamp falls on the pith its temperature will rise, and any moisture on it will begin to evaporate, and to drive the pith from the lamp. The evaporation will be greatest on that ball which is nearest the lamp, therefore this ball will be driven away until the force on the other becomes equal, after which the balls will come to rest, unless momentum carries them further. On the other hand, when a piece of ice is brought near the temperature of the pith it will be reduced, and it will condense the vapor and be drawn towards the ice.

The reason why Mr. Crookes did not obtain the same results with a less perfect vacuum was because he had then too large a proportion of air or non-condensing gas mixed with the vapor, which also was not in a state of saturation. In the experiments the condensable vapor was that of mercury, or something which required a still higher temperature, and it was necessary that the vacuum should be very perfect for such vapor to be anything like pure and in a saturated condition. As soon, however, as this state of perfection was reached, then the effects were more apparent than in the correspondiug case of water. This agrees well with the explanation; for, as previously shown, the effect of mercury would for the same quanity of heat be three times as great as that of water; and besides this, the perfect state of the vacuum would allow the pith (or whatever the ball might be) to move much more freely than when in the vapor of water at a considerable tension.

Of course the reasoning is not confined to mercury and water; any gas which is condensed or absorbed by the balls when cold in greater quantities than when warm would give the same results; and as this property appears to belong to all gases, it is only a question of bringing the vacuum to the right degree of tension.

There was one fact connected with Mr. Crookes' experiments which, independently of the previous considerations, leads me to the conclusion that the result was due to the heating of the pith, and was not a direct result of the radiated heat.

In one of the experiments exhibited at the Soirée of the Royal Society, a candle was placed close to a flask containing a bar of pith suspended from the middle; at first the only thing to notice was that the pith was oscillating considerably under the action of the candle; each end of the bar alternately approached and receded, showing that the candle exercised an influence similar to that which might have been exercised by the torsion of the thread had this been stiff. After a few minutes observation, however, it became evident that the oscillations continued instead of gradually diminishing, as one naturally expected them to do; and, more than this, they actually increased, until one end of the bar passed the light, after which it seemed quieter for a little, though the oscillations again increased until it again passed the light.

The explanation given is that, owing to the slowness with which the pith takes in

and gives out heat, its ends will on the whole be hotter while receding from than while approaching the candle, and hence the force, as a mean, will be greater on that end which is receding, and there will be a continual oscillation.

Since writting the above paper, it has occurred to me that, according to the kinetic theory, a somewhat similar effect to that of evaporation must result whenever heat is communicated from a hot surface to gas.

The particles which impinge on the surface will rebound with a greater velocity than that with which they approached, and consequently the effect of the blow must be greater than it would have been had the surface been of the same temperature as the gas.

And in the same way whenever heat is communicated from a gas to a surface the force on the surface will be less than it otherwise would be, for the particles will rebound with a less velocity than that at which they approach.

It is then shown mathematically, that for every English unit of heat communicated to steam at a temperature of 60 deg., the reaction on the surface is equivalent to 38 lbs. acting for one second; and in the same way for air the force is equivalent to 55 lbs. It is also pointed out that since the diffusion of heat within a gas is inversely proportional to its density, the amount of heat communicated from a surface to the surrounding gas is independent of the density of the gas, and hence, that the reaction on the pith in Mr. Crookes' experiments would remain constant as the vacuum improved, while the counteracting forces would diminish and leave the balls more free to move. It is therefore assumed that the results obtained in those experiments might have been at least in part due to such forces.

THE VENTILATION OF MONT CENIS TUNNEL—ITS APPLICATION TO HOOSAC TUNNEL.

By CHAS. P. HARRIS, C E.

Written for Van Nostrand's Magazine.

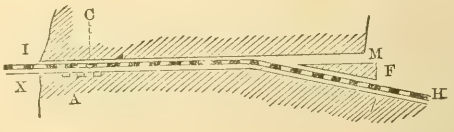
Through the ignorance or carelessness in treating this subject, misstatements have come into public prints that are calculated to give a false impression. From conversation with a French engineer and personal observation, a few facts have been obtained that may be of interest at this time, especially as the completion of the Hoosac Tunnel has given considerable importance to the subject generally, in this country.

Although, before the completion of Mont Cenis Tunnel artificial means were resorted to, in order to keep the air of sufficient purity from noxious gases and fumes of the explosives, since the work has been finished this has been found unnecessary.

It is well known that owing to the great height of the mountain over the tunnel line, a central shaft was impracticable, so the tunnel is largely dependent on the two portals or ends for the admission of air. There are other openings, however, that must be taken into consideration, as may be seen from the following diagram (Fig. 1):

I represents the opening near Bardonneche, on the Italian side. F shows the double exit at Malone the France end. Trains pass in and out at I and H, M being an opening on precipitous side, used as a dump during the construction. A few rods from the Italian terminus, at C, is a shaft, rising some fifty or hundred feet, to a short horizontal secondary tunnel at right angles to the line through which the rock was removed.

Fig. 1.



Between this and the portal are about six semi-circular arches, some 12 ft. in diameter, and only a few yards apart, which open out of the nearly-perpendicular side, at the bottom of the tunnel, to the free air. The shaft on the Italian side and the second portal at the France end, were indispensable in building the tunnel; but, together with the side arches, they form a very important consideration in the ventilation.

The marked difference in the tempera-

ture of the two ends serves to make a natural draft. So striking was this on the occasion of passing through it into France, that the change seemed as great as going from the sunshine into the chilling air of an icehouse.

Among the various methods of artificial ventilation for tunnels, it has been suggested to run trains of cars rapidly through to create a draft, but where this is accomplished by the natural features of the location, it is of course unnecessary to resort to any such increased expenditure.

Let us see the result of passing through the Mont Cenis Tunnel with the ordinary traffic of the road. The most unfavorable circumstances for quick ventilation would be in the case of a train running from the warmer into the colder atmosphere, or from Italy into France, as in this case the rapidity of the current of air would be slower than if the train was going in the direction of the wind, more retarded even than if the train was not in motion. The velocity of the air through the portal, shaft and side openings can be seen immediately after the entering of an engine, for out of each pour great volumes of smoke and steam. The cold air being more or less heated from this, the current is increased and the tunnel sooner freed from impure air. Should the temperature become more nearly equalized at the two ends, there would be a greater tendency for the smoke to become troublesome. But from experiments made at the time referred to, it is thought hardly possible that this will ever prove the least annoyance. One window and then both in the compartment were opened after entering the tunnel, and kept so through a short stop, and the remainder of the trip, all of which occupied about thirty minutes, and the air was not found in the least affected.

In discussing the effectiveness of natural ventilation at Hoosac Tunnel, it must be borne in mind that it is only about half as long as Mont Cenis—nearly $4\frac{3}{4}$ miles (25,031 ft.)—and that unlike the latter, there is a central shaft of considerable size rising near the centre to the surface of the mountain.

Glancing over the early reports of Hoosac Tunnel, written before the practical results of European tunnelling convinced us that long underground passages were feasible, the proper means of ventilation was considerably agitated. Among the plans proposed was the use of engines after its completion, throwing fresh air into the tunnel, thus driving out the impure gases, as is now done, the compressed air running the drills, and ventilating after it is freed.

By the slow progress of the work at the beginning, a central shaft after a few years was under way, thus giving two additional faces from which the work could be advanced. But this was not the only consideration that made the immense additional expense appear warranted to the people of Massachusetts. It was to act a very important part in the ventilation, doing away, many claimed, with artificial means after the tunnel was completed. The argument, in brief, was that the shaft would act as a chimney, making a draft that would take off the impure air, fresh air rushing in from the portals.

That this will not prove the actual result, is shown quite conclusively from a fact that has become known since joining the headings from the central shaft and east end. The observation that the flame of the miner's lamp, during certain hours in the day, indicated the current of air to be in one direction, and reversed at others, is apparently insignificant in itself, but it essentially solves the problem, as to the utility of the shaft in point of ventilation, showing, however, that the theory for a long time held, that the current of air would always have the same direction, is hardly probable.

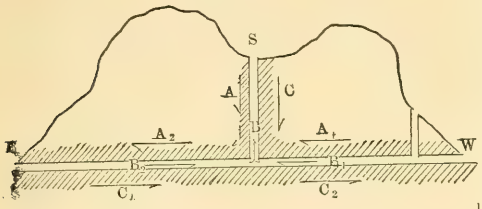
But it is not my purpose to treat of the correctness or incorrectness of certain suppositions. The question that is before us, and the one of most importance to railroad interests is, whether the natural ventilation of Hoosac Tunnel will satisfy the needs of the travelling public. From the results of investigation at both Mont Cenis and Hoosac Tunnels, there appears to be little doubt about it. Although the natural advantages of a cool French climate and the warmer atmosphere of Italy do not exist in the present case, the difference in temperature necessary to cause a draft is practically seen.

The current will not at all times be from end to end through the tunnel, but under certain circumstances passes up through the shaft. Referring to Fig. 2 will illustrate this more fully (the profile is drawn from memory, but is accurate enough for our purpose).

The temperature at the east end, E, being naturally higher in the forenoon than either at shaft, S, or west end, W, a draft

is created in direction shown by the arrows A, A_1, A_2; towards the middle of the day the warmer air at S gives a current shown by arrows B, B_1, B_2; the latter part of the day, just the reverse of what existed in the forenoon, can be seen, and the draft is in the direction of C, C_1, C_2. This is on the supposition that the temperature is not uniform at the three openings. Assuming that it sometimes is so, as is the case when the

FIG. 2.



sun does not materially affect the air, the shaft would act as a ventilator, carrying off the smoke, as represented by B, B_1, B_2, for in this case the atmosphere near the mouth of the shaft, being naturally warmer than the damp air below, rises and makes a current upward. These latter statements are made on no actual experiments by the writer, but are inferences believed to be warranted by reports from reliable authority, and have been practically demonstrated in part. In the observations at Mont Cenis Tunnel, the report was found to be incorrect that trains were not allowed to pass through within half an hour of each other. No sooner had one come out than another was seen entering, the second being a freight train with engine at each end; thus no hindrance to traffic was experienced on the ground of smoke. Whether this will be the case at Hoosac Tunnel, will soon be unquestionably answered.

As far as human foresight can tell, it would seem that an effective and satisfactory ventilation will result from natural causes, and no serious inconvenience be experienced by impure air during the few minutes' ride between the Deerfield and Hoosac valleys.

NOTE.—The writer, having placed the contents of this paper before an engineer several years engaged at Hoosac Tunnel, for perusal, previous to offering it to the press, was advised to have it published, the following brief comments from him, bearing on the subject, are appended:

"In the Hoosac Tunnel the currents of air seem to vary in accordance with the conditions that prevail in different seasons of the year. Whenever the outside temperature is lower than that of the tunnel, then the current always travels towards the coldest point. But whenever the outside temperature is higher than that of the tunnel, then the cold tunnel air seems to move down grade by the force of gravity, toward the warmer side, sometimes drawing the air of the central shaft, and the air of the cooler side after it. * * * *

"There is good reason to believe that there will be no trouble in regard to ventilation."

THE ANCIENT WORK OF THE COPPERSMITH.

From "The Builder."

The subject of the earliest artificers' work in copper, is one that possesses extreme interest, for many different reasons, and it is one as to which much further information than we actually possess is extremely desirable. The chief difficulty that attends the commencement of the inquiry is this. As a general rule, in art, the simpler processes are more ancient than the more complex. Now the production or the working of a metal of any description may naturally be supposed to be more ancient than that of any alloy of that metal. But our earliest relics of any cupreous arms, tools, or other objects, are not, as a rule, of pure copper, but some kind of bronze, or copper alloy. It is perfectly well known that certain alloys of copper are far more manageable by the workman, as well as harder and more available as tools or weapons, than is the pure metal. But we must regard it as probable that a considerable amount of skill had been attained in the smelting and casting of copper, before the ancient coppersmith thought of alloying the metal; and as utensils of bronze so far precede, in the archæological series, any evidence of the discovery and the manufacture of iron, the commencement of this early metallurgic work seems to be pushed back into an almost unattainable antiquity.

The best source of light which we may

now expect to gain on this point is the careful survey of the ancient world, including not only topographical information, but that accurate physical investigation which shall tell us of the source of the wealth of the future and of the traces of the industry of the past. Here archæological research joins hands with industrial inquiry. When we have ascertained, as we may properly hope to do, from what sources the various nations of antiquity, whose history we seek to trace, derived their metals, we shall have the first positive information as to the origin of the various descriptions of ancient bronze.

Copper occurs in a virgin or native state in many places, especially in outcrops. It also occurs in veins, and "pockets," or nodules, which the French miners call *géodes;* where it ramifies into crystals, and into delicate efflorescent threads. In Siberia is found the *cuivre oxydulé*, which resembles a dusky-red stone, sparkling with specks of metal. Black oxides, and blue and green carbonates, known as agarite and malachite, accompany native copper. Specimens of the former are found at Chessy, in France, of a lovely dark-blue, resembling, but darker than, that of the blue vases usually exhibited by chemists. Malachite occurs in the Oural mountains, and its use in Russia as an article of splendor is well known. The ordinary yellow *pyrites* is of frequent occurrence in Wales and elsewhere; and its little bright pyramids and parallelopipedons may readily be mistaken, by the unwary, for gold. The "peacock-copper" of Tuscany has iridescent colors. Like the yellow pyrites, it is a double sulphuret of copper and of iron. The Fahlerz, or grey copper, of the Germans, contains, besides copper and iron, silver, arsenic, and antimony. It is smelted for the sake of the silver and copper, but is extremely difficult to manage, from the complex nature of the ore. But it is highly probable that in this gray copper we have an indication of some of those deposits of natural alloys, which fact suggested to the ancient metallurgist the production of bronze.

Tin,—which, with copper, constitutes true bronze,—is stated in the works on metallurgy to be unknown as a mineralogical neighbor of the latter metal. It is not known to occur in a virgin state. The Cassiterides, or tin island of the ancients, whence this valuable metal was brought by the Phœnician navigators before the time of Homer, are as yet undertermined; though some authors have sought to identify them with our Cornish coasts. Tin is usually found as a crystallized oxide, of a chocolate-brown color, and a form closely resembling rock crystals. More rarely it occurs in what are called stanniferous sands, either yellow, rose-color, or translucent as crystal. It is found in India; supplies at present are derived from Banca and Malacca, as well as from Cornwall. It also occurs in Brittany. The island Vectis of the early navigators, has been explained to lie at the mouth of the Loire; to be the island Saint Michael; to be the Isle of Wight. From each new guess we come to the same result, —the importance of a better physical survey of the Old World.

There is little doubt that, on descending to historic times, tin was brought to the basin of the Mediterranean from India, from Gaul, and from Britain. The mineral was readily separated, by washing, from the sand in which it was found, and then exposed to heat. As the ore is a compound of oxygen with tin, a charcoal fire will effect the reduction of the metal, so that the process has little varied, in principle, from the earliest date to the present time.

No ancient author speaks of bronze, the *æs*, or *cha'cos*, of the Classic writers, as if possessed of any acquaintance with its compound character. The hardening, tempering, and working of bronze is spoken of as we might now speak of the manufacture of iron. When not only the sword and the hunting-knife, but the chisel, the needle, the axe, and the fish-hook were made of bronze, there can be little doubt that the early craftsmen studied and experimented how best to give to their work the hardness of the flint, combined with the elasticity or tenacity of bone.

Very recent discovery has thrown a ray of light on this difficult subject of inquiry. And in the immediate vicinity of Sidon in Phœnicia, have been recovered not only copper mines, but a closely neighboring lode of stanniferous crystals. It is also stated that coal sufficient to carry on the operations of smelting is in the immediate neighborhood. A ridge of hills runs east and west in this part of Syria, terminating chiefly on the coast. Steps are in contemplation for the re opening of these ancient mines. But their discovery is more important as an archæological than as an industrial question. It tends to show that Nature herself

indicated the original mixture of bronze. The position of a source of this alloy in the very headquarters of the most famous mariners of antiquity is another most instructive fact. Hitherto it has been utterly inexplicable why the tin of Cornwall or of India should have been sought in order to mix with the copper of the Mediterranean shores. But when the alloy had once been indicated or casually found, by the smelting of contiguous ores, the search for the rarer metal would have been a natural result. Again, what occurs at Sidon may have occurred elsewhere, and the very earliest bronze may have been indicated by Nature herself.

Brass, which is an alloy of copper and zinc, is a much more modern alloy than bronze. We know but little of its existence before the imperial age of Rome. We find that new brass coins were struck by Julius Cæsar, which Pliny says contained *cadmia* from the Livian mine, and were equal to the excellence of *orichalcum*, for *sestertii* and *dupondii*. *Orichalcum* is sometimes spelt *aurichalcum*, as if it meant copper of a golden color; but its etymology really denotes "mountain copper," and some native alloy was probably first intended. *Cadmia* is taken to mean calamine, or zinc ore. Strabo speaks of a "false silver," which, mixed with copper, became *krama*, or alloy, which some called *orichalcum*. Copper itself is said to have derived its name from the island of Cyprus; and brass, or rather the Greek word *chalcos*, from Chalcis, in Eubœa. The Corinthian brass, which is occasionally mentioned as of extreme value, is generally taken to be the same as *electrum*, or a mixture of gold and silver. Specimens of an argentiferous gold, rich in silver, from Transylvania, are to be seen in the British Museum, under the name of *electrum*, which attract attention from the sharpness of the crystalline forms. As the knowledge of metallurgy passed from a craft into a mystery, and especially when the expectation of being about to discover the secret of the transmutation of metals had seized the imaginations of men, tin was known by the sign of Jupiter, copper by that of Venus, gold and silver by those of the sun and the moon.

The specimens to be found in museums of ancient objects in bronze are numerous and important. We are not now referring to the statuettes and sculptural bronzes, among which may be found some of the most perfect specimens of ancient art anywhere extant. One of the latest additions to the bronze room of the British Museum is a female head, of unrivalled beauty, and also of great interest, as showing much of the method of the ancient workers in bronze. But we rather call attention to such undated specimens as the bronze Etruscan *krater*, found at Capua, with mounted amazons round the rim; and the draped female figure from Sessa, on the Volturno, a town famed for the rare beauty of its women,—one of the most ancient and interesting examples of casting in bronze.

Ancient bronze has not the indestructible character of the precious metals. The disinterment of a vase may, unless special care be taken for its preservation, lead to the rapid crumbling of the object into dust. At Baiæ, near Naples, is an ancient cemetery, in which the different orientation and structure of three super-imposed strata of tombs bear testimony to the successive occupation of the spot by three distinct races. The Oscan, or Etruscan tombs, in this cemetery, which are built of square stones, with a pyramidal roof, not unfrequently contain large bronze vases, of nearly globular form, which are found bedded in a layer of perhaps not more than 6 in. of consolidated dust. The late Count of Syracuse opened many of these tombs, and recovered many interesting objects; among others, the dressing-case of a lady, with implements in bronze. It was his Royal Highness's custom to have the bronze objects plunged into boiling water immediately on being unearthed, which was stated to be the only known precaution against speedy decay.

An extremely interesting question is as yet unsolved as to the method of coinage in use in ancient times, not for copper alone, but for gold and silver. The subject is intimately connected with that before us from the fact that the dies used in coining were exclvsively of bronze or of copper. From the beauty and sharpness of many ancient coins it is evident, not only that the art of the die-sinker, as a matter of graceful taste, was of a very high order, but also that the metallurgic or mechanical part of his craft must have been adequately advanced. That means of hardening bronze, with which we are not now familiar, formerly existed, seems hardly to be questioned. But our most accomplished numismatists speak with no little

hesitation as to the process by which the impression of the die was communicated to the coin.

We are not, however, without some positive information on the subject, although more is still very desirable. The British Museum possesses among its numerous treasures an ancient Roman die. This is an iron implement, formed in two parts, one being a socket, into which the other fits. In the middle of the socket is a circular recess, into which a copper matrix is fitted. The plunger, or upper portion of the die, has a similar recess, fitted also with a copper die. The disc of metal to be struck must have been placed on the lower die, and the guidance of the socket served to bring the upper die into exact opposition to the lower. There is no collar in order to keep the coin central on the die. It is possible that a loose collar may have been lost, but the probability is, that the metal instrument is complete as it exists. The reason for this opinion is the great irregularity with which many ancient coins are struck. It is rare to find the impression central. A piece of unstamped metal is often found on one side, while the device overlaps the metal on the other. This irregularity would, however, have been very natural, if the disc were simply placed on the die by the workman, without any collar to confine it. In the recent improved process for striking coins and medals, a loose steel collar is added, which at once gives a central position to the device, secures the exact roundness of the coin, and serves to mill or ornament the edge. The process may be watched any day at the International Exhibition at South Kensington. It is to be lamented that the modelling of the large gilt medal, which has been recently issued by the directors of that institution to the exhibitors, does not equal the mechanical excellence of the machinery by which it is turned out.

The question remains, of the mode in which force was applied to the dies. The word "struck" is still employed, although it is, in fact, a gradually increasing pressure which is brought to bear on the disc. In the earliest coins it is very possible that a violent blow was actually given to the die. The square depression on the reverse of many ancient coins seems to point to this method of formation. But the British Museum die has not been so treated. It is made of excellent iron, more closely resembling that of Styria than any now commonly made, but which we believe to have been procured from the Apennines. But the plunger, or upper part of the instrument, has no marks such as a series of violent blows would have occasioned. Our readers who are accustomed to the blacksmiths' sets will understand what we mean.

We think the inference is unavoidable, that the iron must have been inserted in wooden blocks; and that pressure must have been applied as it is in the oil-presses and the maccaroni-presses of Italy, at the present day, by the combination of the lever and of the screw. The habits of the peasants and lower classes of the Peninsula, especially in the wilder parts, as in the Abruzzi and the Calabrias, are wonderfully little changed since the imperial times. At Canosa, for example, the very same grittiness in the bread which Horace deplores in his journey to Brundusium still endangers the teeth of the eater. The mode of applying enormous pressure which is now in use is, there can be little question, as ancient as it is effective. Rude in its details, it is essentially in principle one with the latest machinery of our mints.

The dies in the instrument which we are describing seem to be of copper, and bear marks of rough usage. But it can hardly be doubted that among the Greeks, and probably the Asiatic nations, hardened bronze was employed. Some of the vexed questions as to ancient coins hinge, to a great extent, on this subject of the hardness of the die. Thus when coins are found very closely resembling one another, but not *fac similes*, it is supposed that they are produced by different dies cut and used in the same year. This, of course, is possible, although it is also possible to ride such a hobby to death. Thus De Sauley figures, in his "Recherches sur la Numismatique Judaique," plates xiv. and xv., eight copper issars, or assarions, which differ very widely in their treatment of the palm-tree and the vine-leaf which they bear, in the arrangement, and even in the type or form of the letters on the field; and ascribes them all to the same year,—viz., 134 of the Christian era. This extraordinary attribution is only brought within the limits of possibility by the assumption of the use of numerous dies in the same year,—an assumption, however, that does not account for the artistic and paleo-

graphic differences of the pieces in question. It has been clearly shown by a writer in an important contemporary publication ("Bible Educator," parts xiv. and xv.), that the year II. on these coins refers to the second year of the seven, a constantly-recurring date, the distinction of which, on the coins used for sacred tribute, was important. Thus the absurdity of attributing 30 per cent. of all the known Jewish coins to at the outside 9 out of 184 years, will, it is to be hoped, not disfigure any further works on coinage.

The distribution of copper over the surface of the earth is wide and abundant. In the Old World it occurs in Asia Minor, Italy, Spain, France, Morocco, Algiers; as well as in Persia, Abyssinia, Congo, the Cape of Good Hope district, and Madagascar; and in England, Germany, Sweden, and Russia. It occurs on the shores of Lake Baikal, in China, and in Japan. It is found in Australia. In the New World it occurs in Canada, in the United States, in the Antilles, in California, and in Chili. It tinges the promontory of Cape Farewell. These are only the best known and more conspicuous deposits, as they appear on the face of the map. In Russia, copper mines were worked, in prehistoric times, in Siberia, in the Bashkir land, and in the Kirghis steppes, by a people of whom we have no account. Early in the present century the now famous mines of Nijni Tagil were commenced; and soon after it was discovered that the whole of the eastern slope of the Oural, from Voskresensk in the extreme north, to near the village of Malvatinea in the extreme south, abounded, more or less, in copper. Tin is also found in the Oural, though it is not now worked. The yield of the ore at Nijni Tagil, from 1814 to 1830, was above 3 to 4 per cent. In 1836 it rose to 5 per cent.; from which it has gradually dropped to half that proportion. The depth of the mines here is ninety fathoms. Near Simbeisk, in former times, it was found profitable to work a copper ore which contained only two per cent. of metal. Old clay pots have been found here, which were used by the early smelters, and which indicate from their great rudeness, a richer ore, as no results could be obtained from the present ore by so rude a process. At the fair at Nijni Tagil copper ore sold, in 1870, at from 2½ to 3 kopecks per pood, being equal to from 3s. 11d. to 4s. 8d. per ton; so that the copper is made for £47, 5s. per ton. The Oural mountains yield, besides copper and tin, gold, silver, lead, sulphur, chrome ore, diamonds, jasper, marble, talc, alabaster and steatite.

Spain was the great source of the supply of metals for the Romans, as well as for their rivals, the Carthagenians. Ancient mines have been discovered in the Spanish peninsula, some of which have been resumed with profit. Veins of copper and tin, as well as deposits of lead, of iron, and of antimony, await the industry of the Spaniard, whenever the good time shall arrive when Spaniards become industrious.

In the Alpine districts, Piedmont is rich in metalliferous strata. The Val d' Aosta is rich in copper pyrites, as the Val d' Anzasca is renowned for gold pyrites. The mountains which border the Gulf of Genoa are rich in copper. The hills of Modena, famous for their quarries of Carrara marble, contain copper, as well as iron, lead, and silver. On the north portion of Tuscany are found veins of argentiferous copper. From the mines of Campiglia the bronze of the ancient Etrurians is said to have been derived. In fact, the whole western slope of the Apennine chain, running to the south-east from the shore of the Gulf of Genoa, is rich in metalliferous strata. The silver which formed the materials for the famous coinage of Syracuse, was derived, it is thought, from the Calabrian Apennines.

From this hasty glance at the regions whence much of the metal used in the bronze period must have been derived, indications may be grasped which the advance of physical geography will convert into positive sources of knowledge. It would seem that copper, like gold, existed in a virgin state, and that the native lodes and the richer ores were successively exhausted, until the ore became too poor to repay the rude process of the ancient smelter. It also appears clear that, in certain places, as at Sidon and in the Oural, tin is even now found in close proximity to copper. In other places calamine, or zinc ore, is found near copper lodes. We infer that both bronze and brass were thus, in the first instance, the natural products of certain rich lodes or ores. As these, in the long lapse of time that preceded the use of iron, became exhausted, commerce, taught by metallurgy, sought the rarer metal, tin, in those spots whence it is now derived.

PROGRESS OF THE IRON AND STEEL INDUSTRIES.*

By DAVID FORBES, F.R.S., etc.

From the "Journal of the Iron and Steel Institute."

Annual make of Iron and Steel in the World.—In the third Quarterly Report for 1872, were produced from American sources an approximate estimate of the total production of cast iron on our globe during the year 1871, and now we present a similar one, compiled from the most reliable sources at our disposal, which will probably be found to be a still closer approximation to the truth :—

		Tons.
Great Britain	1873 ..	6,741,929
United States of America	1873 ..	2,695,000
Germany..	1871 ..	1,664,802
France	1873 ..	1,381,000
Belgium	1872 ..	652,565
Austria, with Hungary	1871 ..	424,606
Russia	1871 ..	354,000
Sweden	1872 ..	322,000
Luxembourg	1872 ..	300,000
Canada	— ..	160,000
Italy	1872 ..	73,709
Spain	1870 ..	54,007
Norway	— ..	20,000
South America	— ..	15,000
Japan	1871 ..	9,370
Switzerland	1872 ..	7,500
Asia	— ..	40,000
Africa	— ..	20,000
Australasia	— ..	10,000
	Total ..	14,885,488

Wherever possible, the date of the last official returns is given in the above statement, which, as it stands, indicates that the present annual production of cast iron in the world amounts to at least 14,885,488 tons, as compared with 13,315,000 tons stated in the former estimate, 13,825,000 tons in the official report of the Vienna Exhibition, and 12,455,000 given in Wagner's Chemische Technologie, 1873.

Africa.—All accounts from Algeria concur in representing the development of the iron mines of this colony as becoming every day of more importance. The iron mine Ain-Mokhra, or Moktael-Hadid as it is more commonly called, is being worked most successfully, and has exceeded in its production the most sanguine hopes of its owners. Before the Franco-German war the output of iron ore from this mine had reached some 20 000 tons per month, and although during the war it declined greatly, it has now reached more than 30,000 tons per month, and at this moment some eight trains, each of 200 tons, or 1,600 tons in all, are sent per day down to the port of Bona.

Australia.—According to last accounts, the South Australian Steel and Iron Company has commenced operations at Mount Jagged, and some eight lodes of iron ore, containing between 50 and 60 per cent. of metallic iron, and from 30 to 40 feet across, are reported to have been discovered near Ballarat.

From Victoria accounts of new discoveries of valuable deposits of brown hematite and magnetic iron ores have been received, it being further stated that these are situated in close proximity to limestone, fire-clay, coal, and a railway station.

Austria.—Since the financial crisis of last year, the state of the iron trade of this country has been anything but satisfactory, and many new undertakings previously commenced, as among others, the great blast furnace establishment of Dr. Strausberg, have, it is reported, been stopped for the present, or abandoned. Excepting some smaller iron works scattered over other parts of the country, and the lesser iron districts of Moravia, Galicia, and Lower Hungary, which each produce something between 30,000 and 40,000 tons of pig iron per annum, the bulk of the Austrian iron manufacture is confined to the three great centres: Bohemia which turns out about 130,000 tons; Styria and Carinthia, producing some 178,000 tons; and upper Hungary, with a make of some 100,000 tons of pig iron yearly; of these three districts Bohemia is the only one provided with extensive coalfields, which, although at present comparatively but little developed, must soon assume much greater importance from the numerous railways which have lately been constructed, or are in course of construction, for placing them in communication with the iron ores and the rest of Austria. The Adalbert Huette at Kladno, recently visited by the author, contains six blast furnaces, with extensive foundries and rail, girder and bar rolling mills, which are stated to have turned out of late years some 35,000 tons of rails, girders, etc., per annum; at present, *i.e.*, in June, only one blast furnace is in operation,

*Abstract of the report to the Iron and Steel Institute.

and most of the mills are idle. A remarkable feature in these works is the carrying out on the large scale of Mr. Jacobi's (who is director of the establishment) process for dephosphorizing the iron ore previous to its being smelted in the blast furnaces, for a description of which we refer to the technical part of this report.

In Styria, the puddling of iron is almost altogether effected by the employment of brown coal or peat as fuel. The latter material is successfully used at many works, and when burnt in Siemens's regenerative puddling furnaces gives from nine to ten charges of 400 lbs. each, with a loss of 5 per cent. and a consumption of 16 cubic feet air-dried peat, whereas the quantity of peat required for puddling in an ordinary furnace is as much as 24 cubic feet per 100 lbs. of puddled bars.

Belgium.—The condition of the iron trade in this country has been most unsatisfactory to all concerned therewith; many blast furnaces have been kept idle, and most of the other works have been but barely paying their way, while the sale of Belgian pig iron has been much affected by the competition of the Luxembourg ironmasters, who have been selling in opposition at any prices obtainable. For some months past, owing to the strikes in England, the Belgian prices became so much lower than those here, that very considerable orders for girders, plates, and even rails were obtained in England, and Belgian iron of certain classes has been successfully competing with the local produce in the midland counties. It is worthy of remark, however, that, in spite of this competition, no less than 3,806 tons of English railway iron were exported to Belgium during the month of May, 1874, as compared with 1,166 tons in the same month 1873, and only 470 tons in May, 1872. The Belgian exports of iron to Ge many seem to be getting less and less.

The general feeling of the Belgian ironmasters is strongly in favor of a law being passed for the granting of concessions by the Government for all deposits of iron ores, which cannot be worked open cast, but can be explored by shafts or adit levels; the Minister of Public Works has been petitioned to this effect by the Association des Maîtres de Forges, and the subject has also been taken into consideration by the Comité Métallurgique de Liège.

France.—From the Bulletin du Comité des Forges de France, No. 87, we extract the following statistical details of the production of iron in France during the last year:—

Production of Cast Iron in France during the year 1873.

	Foundry Pig	Forge Pig.	Total in Metrical Tons.
Total for 1873.	252,834	1,129,111	1,381,945
in 1872.	173,806	1,007,455	1,181,261
Increase in 1873.	79,028	121,656	200,584

The total production of pig iron in last year is thus seen to have attained the figure of 1,381,957 metrical tons; 200,695 tons in excess of the previous year's production, and only about 16,000 tons less than the production of 1869—1,398,000 tons—which was the greatest quantity of cast iron ever made in the course of one year in France. The manufacture of wrought iron in 1873 did not bear the same relations to that of 1872 and 1869 as was the case with the cast iron; for here we find the increase only to be 23,666 tons over 1872, while the difference between the figures of 1869 is still more marked, being some 126,000 tons less than the production of wrought iron in France during the year 1873.

With regard to steel, the production of steel of all kinds during 1873 attained the figure of 167,677 metrical tons, against 138,552 tons in 1872, or an increase of 29,124 tons, which shows that this manufacture still continues increasing at about the same rate as before, as will be seen from the following figures:—

1863,	total production	was	1,856 metrical tons.
1864,	"	"	6,750 "
1865,	"	"	9,751 "
1866,	"	"	10,790 "
1867,	"	"	19,893 "
1868,	"	"	42,601 "
1869,	"	"	52,400 "
1870,	"	"	90,000 "
1871,	"	"	110,000 "
1872,	"	"	138,552 "
1873,	"	"	167,677 "

The quantity of steel of all kinds imported into France, during the year 1873, amounted to 6,658 metrical tons.

The following figures indicate in metrical tons the total amounts imported into France

during the years 1873 and 1872 respectively:—

			De-crease.	In-crease.
Cast iron	125,996	129,805	3,809	—
Wrought iron and steel	54,882	43,676	—	11,206
Total ..	180,878	173,481	—	7,397

On the other hand the total quantity of cast and wrought iron, steel, and manufactured articles exported, are returned as follows:—

For 1874 at 272,924 metrical tons.
" 1873 " 259,160 "

Thus showing a diminution 13,764 metrical tons in last year's exportation, or about 5 per cent. on the whole amount.

The quantity of iron ores imported into France in 1873 shows an increase of 52,000 tons on that of the preceding year, this augmentation being due in the main to iron ores received from Belgium, Germany and Elbe, since the quantity of ore imported from Algeria has but slightly increased, and that from Spain has been less on account of the disturbances in that country.

According to the Bulletin du Comité des Forges de France, for February, 1874, the consumption of rails by the different lines throughout France amounted in 1873 to 199,359 metrical tons, of which 133,261¼ were iron, and 66,097 steel rails, which figures may again be subdivided into

124,717 tons	iron and	64,077 tons	steel rails made in France, and
8,543	"	2,000 tons	steel rails imported from abroad.
133,260	"	66,077 tons	steel rails,

in addition to which, 18,085 tons of iron and 35,781 tons of steel rails made in France were exported in 1873.

During the first four months of the present year, the importation of pig iron amounted to 35,041 tons, against 53,154 tons during the corresponding period of 1873, while that of wrought iron is given at 13,166 tons against 18,913 tons in the first four months of last year. The importation of steel in the same period was 2,429 tons, as compared with 1,995 tons in 1873. The exportation of cast and wrought iron and steel during the first four months of this year amounted to a total of 72,147 tons, against 75,132 tons exported from France during the corresponding period in 1873.

The above figures show a diminution of some three per cent. in the importation, and 4 per cent. in the exportation, during the first four months of this year, as compared with the corresponding period in 1873.

At the commencement of the year the state of the iron manufacture in France was extremely unsatisfactory, and but little better than in Belgium; many furnaces were out of blast, and in most districts there was but little sale for the products, and very few orders on the books. The iron works in the basin of the Loire were, however, an exception to this state of things, and with them prospects were not so discouraging. At the end of March the horizon appeared clearer, and the state of things became somewhat better, but still it was far from satisfactory. During all this time the Creuzot works, with their twelve blast furnaces, and about 15,500 hands employed in the works and mines seem to have been fully occupied, and much satisfaction was expressed at their having obtained an order for 10,500 tons of rails for Alsace and Lorraine in opposition to both English and German tenders, among the latter being those of Krupp and Bochum.

Much interest has been shown in the process of M. Euverte for making steel from inferior pig irons (which contain more phosphorus than can be dealt with in the Bessemer converter) by the employment of ferro-manganese, and a company has been formed in Paris with a capital of six million of francs, entitled La Société des Fers et Acieres par Alliages des Manganèse, the objects of which, as expressed in its prospectus, dated Paris, 21st March, 1874, are thus stated:—

1. The sale and manufacture of alloys of iron with manganese.

2. The application of such alloys to the production of soft metal.

3 The application of such alloys to the production of steel containing more or less phosphorus either by the Bessemer or Siemens-Martin process.

4. The establishment, partial or complete, of works for such manufacture.

Germany.—The total production of iron ores of all descriptions in the Prussian provinces in 1872 amounted to 3,671,367 metrical tons, valued at 11,389,240 Prussian thalers, or about £1,708,300 and

which gave employment to 32,229 workmen, besides 56,040 women and children.

The production of pig iron in the Prussian States, in 1872, exceeded that of any previous year, amounting (castings direct from the blast furnace included) to 1,457,825 metrical tons, valued at between eight and nine millions of pounds sterling, and being an increase of 12.3 per cent. in quantity, or 60.5 per cent. in value, on the production of the preceding year, or, if compared with 1868, an increase of no less than 38.4 per cent. in quantity, or 121.6 per cent. in value. The augmentation in value, owing to the much higher prices which have ruled for pig iron of late years, is naturally greater in proportion than the increase in the quantity of pig iron made.

The production of the forges of the Prussian States in 1872 amounted to 852,902 metrical tons, to which may be added 121,227 tons re-worked from blooms and scrap, etc., which is regarded as being an increase of more than 37 per cent. on the production of the previous year.

The statistics of manufactured iron show the produce to have been—

	1872.	1871.
From the forges using pig iron alone	774,132	723,892 tons.
From the mills using wrought scrap and blooms	120,399	134,121 "
Total	894,531	858,013 "

The figures of 1871 are, however, considered as too high and not to be relied upon as in the case of 1872. The details of the iron manufactured from pig direct in 1872 are given as follows :—

	Metrical Tons.
Rails and fish plates	197,938
Railway axles and wheels	12,028
Profile iron for building, etc.	68,665
Heavy plates, etc.	23,324
Other undescribed iron	323,432
Plate and sheet	81,809
Tin plate	2,372
Iron wire	74,527
Drawn pipes	35
Total	784,130

According to the official statistics, the manufacture of steel of all kinds in the Prussian provinces employed 21,531 workmen, distributed in 58 steel works, and resulted in the production of

	Metrical tons.	Valued at about
Crude Steel	113,149	£1,945,350
Cast Steel	174,755	2,772,327
Total in 1872	287,904	4,717,677
as compared with 1871	235,175	4,074,072
also an increase in 1872 of	52,729	643,605

but as the classification adopted for the different varieties of steel was different in 1872 from what it was in 1871, so that, for example, much of what was entered as cast steel in 1872 is to be found under the heading crude steel in 1871, any comparison between the details of the production in these respective years is useless; but the quantity of steel manufactured in the Prussian provinces in 1872 is given below, with the explanation that under the name of crude steel it appears to be understood all steel made by the hearth, puddling, cementation or Bessemer processes, while the term cast steel (notwithstanding that Bessemer steel is certainly entitled to that appellation) seems to be confined to such as is made by the Siemens-Martin and crucible processes.

Production in 1872. Province.	Crude Steel. Metrical Tons.	Cast Steel. Metrical Tons.
Brandenburg	—	302
Silesia	4,553	—
Saxony	331	—
Hanover	14	15,334
Westphalia	50,318	79,879
Hesse Nassau	703	—
Rhenish Prussia	57,526	79,239
Total	113,445	174,754

while the actual return of manufactured steel of all kinds for 1872 is given as follows :—

Rail and Fish plates	149,010
Railway axles and wheels	65,302
Heavy plates and parts of machines	6,778
Cannons and Balls	6,592
Other Steel Articles	42,766
Sheet Steel	2,904
Steel Wire	250
Total	273,602

From the following figures, the proportion which the steel manufacture in Prussia

bears to that of the entire German Empire, and the wonderfully rapid rate at which this industry has increased during the last ten years, can be seen at a glance:—

	German Empire.	Prussia.
	Tons.	Tons.
1862	40,916	40,160
1863	54,250	53,254
1864	71,359	70,409
1865	99,543	98,209
1866	114,433	113,603
1867	122,591	122,148
1868	122,836	122,358
1869	161,819	149,366
1870	169,951	157,961
1871	254,514	235,176
1872	?	287,905

Greece.—According to official reports from Syra, a considerable quantity of iron ore has been exported by the Hellenic Metallurgic and Mining Company from the Island of Seriphos to England. It seems that the first shipment was made in 1872, and up to the end of October, 1873, seven steamers had carried some 8,000 tons of the ore to Newcastle, where it is reported to have been successfully smelted with a yield of 64 per cent. pig iron in the blast furnaces of the Royal Greek Iron Works near that town, which were alluded to in one of our former reports. The quality of the Seriphos ores is said to be equal to that of the best Spanish or Swedish iron ores, and a consignment of some 500 to 600 tons has been shipped from Seriphos to Koumi, in order to make an experiment in smelting it with the coal found at that place.

India.—During the six months ending September 30th, 1873, 5,690 cwts. of cast iron were imported into India, as compared with 3,819 cwts. during the corresponding period of the preceding year, and 7,203 cwts. during that of 1871, the whole of which, with the exception of 90 tons, was received from England. Of cast steel, 2,854 were imported, as against 10,709 cwts., and 18,379 cwts. in 1872 and 1871 respectively. In October last year, the importations of cast iron were 1,800 cwts., as compared with 330 cwts. last year, and 1,100 cwts. in 1871; while of steel 1,766 cwts. were imported, as against 1,583 cwts. in 1872, and 765 cwts. in 1871.

In the Records of the Geological Survey of India, will be found a communication by Mr. Theodore Hughes, entitled "Note on some of the iron deposits of Chanda, Central Provinces," which gives a description of some of the deposits of iron ore long worked by the natives in that district, as well as some details of the primitive mode of smelting still carried on at present in this part of the world, from which we venture to make a few excerpts as interesting, if only by showing how vastly different the scale is on which the manufacture of iron is conducted in different parts of the British Empire in the nineteenth century.

The native furnaces of Chándá are somewhat higher and larger than those of Bengal, being nearly 6 ft. in height, owing to the front face being carried upwards in order to back the ore around the feed hole. The height of the actual smelting shaft is from 4 ft. 6 in. to 5 ft., and its internal section that of a cone diminishing in diameter from 18 in. at a height of 6 in. above the hearth, to 9 in. at the height of 3 ft. above it. The hearth, as is usual, slopes from behind forwards, and the bloom is taken out through the face. The tuyeres are 9 in. long, $1\frac{1}{2}$ in in diameter behind, and $\frac{3}{4}$ in. in front, and they are supplied by bellows usually worked by hand.

The iron thus obtained is called "kit" by the Maharattas, and is a mass of spongy iron slag and charcoal, which has to undergo two refinings before it is considered proper malleable iron. The first of these operations is effected by the men who reduce it from the ore. They heat it in a refinery until the slag is more or less expelled, and the iron consolidated to a compact bloom, during which operation it loses so much in weight that a mass formerly weighing some 14 seers, will be diminished to 10 seers; the charcoal employed being, it is said, some 20 seers, or a little less. These blooms are then cut nearly in halves, when they are called "chúl," and sold to the regular metal workers (lohars), who work them over again, by which from one-third up to even one-half the weight is lost, and then it is made into the various agricultural or household articles in general use.

Taking the mean of the Múhl figures, it appears that:—

(*a*) $17\frac{1}{2}$ seers of crude iron are produced from smelting 63 seers of ore with 87 seers of charcoal.

(*b*) In the first refining, 20 seers of

charcoal are used, and the iron loses 5 seers in weight, thus reducing it to 12½ seers.

(*c*) In the final refining, about 10 seers of charcoal are consumed, and the result is from 7 to 8 seers of clean workable iron.

Thus, according to Mr. Hughes, 8 seers of malleable iron require for their production 63 seers of ore, and 117 of charcoal, which, reduced to English weights, are equivalent to 8 tons of ore, and 14½ tons of charcoal to the ton of wrought iron.

Italy.—The total quantity of iron ore exported from the Island of Elba, in 1872, amounted to 114,936 metrical tons, of which 53,023 tons went to France, 29,045 tons to England, and 32,868 tons to the mainland of Italy.

The company to which three of the principal mines at Rio were made over in 1851, for thirty years, by the Grand Ducal Government of Tuscany, as a guarantee for a loan of 10 millions of francs to that government, has signed an agreement with a French metallurgical syndicate, to supply 140,000 tons iron ore per annum for a period of eight years, dating from the 30th June, 1873, or in other words, for the remainder of the original lease—and have also made a mutual agreement with M. Brioschi, that they shall not send ore into the English or French markets, unless by special accord. A contract had previously been made by M. Sella, in the name of the Italian Government, with M. Brioschi, by which the two other iron mines of Calamita and Terranera, situated near the Port of Rio, are ceded to that gentleman for working up to the 30th June, 1881, and after that date, of the whole of the iron mines of Rio, for the term of thirty years, obliging him on his part to construct, within three years, a railway from the mines to the port, the necessary stations and piers for loading and discharging the ore, and ironworks capable of producing 35,000 tons pig iron or steel per annum, he being allowed to export iron ores to England in order to lighten the price of the coke necessary for smelting the iron ores, by providing return freights for the ships employed in its carriage.

Japan.—According to the official report of the Vienna Exhibition, the production of iron in Japan, during the year 1871, amounted to 9,370 tons. From San Francisco, in California, we learn that the Pacific Iron Works are now engaged in constructing machinery for smelting and rolling iron in Japan, which consists of steam engines with boilers, blowing machinery, ore crusher, ironwork for furnaces, bloom squeezer, steam hammer, shears, etc. The ore deposits, which are said to be extensive, are reported to be native magnetic oxides containing from 60 to 65 per cent. metallic iron, and of excellent quality. The machinery, in the first instance, will be shipped to Yokohama, whence it will be reshipped to the district in which the mines are situated.

Luxembourg.—The production of cast iron in the Grand Duchy has immensely increased of late, as will be seen from the following figures:

	Metrical Tons.
Make of pig iron in 1865	55,000
" " 1868	115,000
" " 1870	150,000
" " 1872	300,000

The extremely large stock of pig iron held by the Luxembourg ironmasters during the first half of the present year, and the evident determination they have shown of selling it at any price, has been seriously affecting the Belgian markets of late.

New Zealand.—The last news from this colony states that a company, entitled the New Plymouth Iron Sand Company, has been formed, and that its representative, Mr. Parris, had fixed upon a site for the erection of a furnace, and had concluded negociations with the natives for the purchase of the land required for the operations of the company.

A company, entitled the Parra Parra Iron and Coal Company, is being formed in Melbourne, for working an iron mine in the province of Nelson and the Collingwood Colliery adjacent thereto. Some of the ore has been smelted by Messrs. Drysdale and Frazer, and yielded over 40 per cent. metallic iron; and in a late number of the "Melbourne Argus," we find the following paragraph, relating to the prospects of the establishment of ironworks in New Zealand; which we reproduce verbatim, without making any comments on the correctness of the statement contained in it:—

"We learn that a company is in course of being formed in Melbourne, for the purpose of utilizing the discoveries of iron lately made in the province of Nelson, in New Zealand, on the shores of Massacre Bay. A prospectus has been issued, from which we gather that the ore is of extraordinary

richness, and the iron produced of the most superior quality.

Russia.—The Russian Government are endeavoring to encourage the development of the manufacture of iron in the country, by making, in their contracts for railway materials, the obligation on the contractors that these must be entirely of Russian manufacture. The iron trade in the Ural districts is described as being at present in a very prosperous condition, the prices being good, and the demand, more especially for Siberia and Central Asia, great and rapidly increasing.

M. Inostrantsev, who was, in 1873, engaged in a geological examination of the province of Olonetz, has reported the occurrence of immense deposits of coal and iron ore, and the council of that province has decided to apply to the Imperial Government for permission to open up and work these mines, which it is expected will be granted.

Spain.—At the Vienna Exhibition, the Compania de Minas et Hierros del Pedroso, near Seville, was awarded one of the medals of merit, for the iron ores and products of its furnaces and forges. This company possesses immense deposits of magnetic and specular iron ores of the finest quality, but owing to the increasing scarcity of charcoal, is not able to keep more than one of its three blast furnaces in steady work. The forges are provided with Siemens's regenerative puddling and reheating furnaces, and trains of rolls driven by water power; and now that the works will be immediately placed in communication both with the coal basins of Villeneuva and its own iron mines, by the railway nearly completed, the company will be in a position to work on a scale commensurate with the extent and richness of the iron mines.

In the Vienna Exhibition attention was also directed to samples of the iron ores exhibited by Sr. Hysern, from the mine of Calataunas, in the province of Granada, not more than some 15 miles from a harbor, the ore being, it is stated, visible on the surface for a distance of nearly two miles, and more than 600 feet in width. Its analysis shows 64.2 per cent. metallic iron, with 7.47 per cent manganese, but no phosphorus, and only 0.057 per cent of sulphur.

Sweden.—We have not as yet received the official statistics of the iron trade of this country for 1872, but we understand that the quantity of cast iron produced in 1872 amounted to 322,000 tons, as compared with 292,850 tons in 1871, and that of wrought iron to 193,000 tons against 183,989 tons in the preceding year.

The following analyses of Swedish iron ores are published by Mr. J. F. Lundberg, in Jern Kontorets Annaler for 1873, p. 320 and 321.

	A.	B.
Protoxide of Iron	81.05	82.62
" Manganese.	0 15	trace.
Silica	14 20	12 21
Alumina	3.31	3.18
Lime	0 98	0.67
Magnesia	0.47	0.45
Total	100.16	99.13

A. Magnetic oxide of iron from Femmand mine in South Graengesberget, which contains 63.83 per cent. metallic iron.

B. Iron ore from Svederna Mines, in the province of Kalmar, contains 64.27 per cent. metallic iron.

Tasmania.—Letters received from Tasmania give some information as to the proceedings of two recently-formed companies engaged in working the rich deposits of iron ore found near the river Tamar, on the north side of the island. With respect to the Charcoal Company, a tramway of some 4½ miles from the jetty on the riverside reaches the works, where an experimental furnace has been erected on a new patented system, some few hundred yards from the deposit of iron ore called the Hill of Vulcan, which appears from the accounts to be an enormous mass of red hematite and magnetic oxide of iron, free from sulphur, and containing some 60 per cent. of metallic iron. There are dense forests in the immediate neighborhood. Other deposits of iron ore also occur on the company's property, which extends over 450 acres of land.

Turkey.—As regards the development of the iron and steel manufactures of this country, we have not been able to obtain any definite information, and the state of these industries, as represented at the Vienna Exhibition, did not appear to be much more advanced than at the Paris Exhibition of 1867.

Among the most important ironworks appear to be those at Samakow, in the Balkans, which contain some twelve blast

furnaces, and turn out annually about 12,000 tons of wrought iron of excellent quality. The works at Routcha also produce about 5,000 tons of pig iron, and the ironworks of Klissoura, Palanka, and R'cka, whose production is not given, are supplied with iron ore from the mines of native oxide, situated in the valley of Novada and Klissoura—mines of hydrated oxide of iron are worked at Karatova.

THE STORAGE OF WATER.

By J. BAILEY DENTON, C.E., F.G.S.

The Amount of Rain Falling on the Surface of England and Wales.

The area of England and Wales is 37,324,883 acres, and the mean annual quantity of rain falling on an average of years on this surface may be taken at 32 in. Dalton, fifty years back, estimated the average annual rainfall of these portions of the United Kingdom at 30 in.; and, in the absence of actual records sufficiently numerous and evenly distributed to be relied upon, this estimate was a remarkably sound one. Since then, great efforts have been made to supply this deficiency, and thanks to Mr. Symons, we are now in a position to state with some degree of certainty as to the quantity of rain falling on the surfaces of the numerous districts characterizing the country, and have been enabled, by the information he has collected, to arrive at the maxima, minima, and means of those several districts, and then to strike the averages of years. Mr. Symons tells me that he considers the average mean rainfall of England and Wales to be 32 inches, and, having carefully examined the returns published by various authorities, I have been enabled to confirm, and therefore adopt his estimate.

It may be interesting to show how this quantity is arrived at. Dividing England and Wales by the outcrop of the Lias formation which runs from Whitby and Redcar in Yorkshire on the north, to Lyme Regis in Dorsetshire on the south, in a tortuous but nearly unbroken line, I find the mean of all recorded averages on the east of that line to be nearly 26 in., the extreme being 20 in. in parts of Essex (minimum), and 36 in. in a part of Sussex (maximum). This division contains rather less than 16,000,000 of acres. On the west of the Lias the average rainfall is 38 in., the extremes being less than 30 in. in parts of Gloucestershire and Shropshire (minimum), and upwards of 60 in. in parts of Wales, and 80 in. in the Lake district (maximum). This division contains about twenty-one and a-half millions of acres, and in it are included the Devonian hills of the Southwest of England, the silurian range of hills of Wales, and the carboniferous limestone hills of the north, which together form the Alpine range, and rise above the new and old red sandstone formations and the coal measures. The first described division consists of surfaces of which about two-thirds are porous. They form the outcrop of the water-bearing strata known as the chalk, the greensand, and the oolite; the remaining third being comparatively impervious clay soils, which resist more or less infiltration of the rainfall. The heights of this division above sea level will vary from 10 ft. in Lincolnshire to upwards of 700 ft. in the Downs of Sussex, Hants, and Wilts, with a large proportion exceeding 200 ft. The other division presents a much smaller proportion of absorbent surface, the principal formation of that character being the new red sandstone, which, though forming in itself a wide area, really presents but a small proportion of the whole. The remainder of the division consists, as already stated, of the Primitive, Transition and Early Secondary Rocks, which for the most part are covered but thinly with detritus of those rocks and vegetable matter. The height varies from a few feet to upwards of 4000 ft., with a considerable proportion more than 400 feet above sea level.

Deferring for a time an explanation of how these physical conditions affect the question of water-storage, I should point out that every inch of rain falling on an acre of space supplies 22,622 gallons of water. Now if we first multiply this number of gallons by 32, the number of inches representing the average rainfall, and then the total obtained by the number of acres forming the area of England and Wales, we arrive at the immense total of 27,019,632 millions of gallons as the quantity of

water which on an average of years falls on the surface at the feet of the population, exclusive of the deposition of dew, which forms no very small nor unimportant item in the water economy of the country. Though the figures I have just given are, from their number, difficult to appreciate, it is most desirable we should comprehend their full magnitude at a period in our social condition when we are compelled, by the rapid increase of population, to secure a full supply of water as an essential to the public health, and when we are obliged, by the equally rapid strides of trade and commerce, to look forward to the time when the supply of coal may be exhausted, or its price advanced to a famine rate, in consequence, in a great measure, of our neglect of that element—water—with which Providence has furnished us, and which has ever been at hand as a natural and inexpensive source of motive power.

The Quantity of Water required for all Purposes.

The quantity of water required in our sanitary arrangements and for domestic and trade purposes amounts to a very small proportion of the large quantity of water which I have just given. The quantity of water actually consumed at present varies from as little as two gallons per head per diem in villages and isolated places where the water used is obtained by personal labor, to from 30 to 50 gallons per head per diem in some of our cities and towns where public supplies and considerable waste exist. The average quantity used throughout England and Wales for *all* purposes is probably not much more than 15 gallons per head, though it may be well to allow that before the next 20 years have passed the increasing demand for water for all purposes will raise this quantity to a mean of 25 gallons. Now, if the population of England and Wales, which reaches 25 millions, is multiplied by 25, it will amount to 625 millions of gallons per diem,or 228,125 millions per annum. To this requirement of the population we must add the water which is wanted by animals and farm stock scattered throughout the country, and which are not provided for in the water supply of towns. The number of horses, cattle, sheep, pigs and dogs does not much, if at all, exceed 50 millions, and if we consider that on an average each animal uses and wastes 5 gallons per diem, the total result will be 250 millions of gallons per diem, or considerably less than half the quantity required by the population. This quantity has to be supplemented by the water consumed in the production of steam used in manufacture as well as that which is used at the homestead or in the field, and which I hope will be greatly increased. This, however, even if we allow that steam-power to the extent of from 10,000 to 12,000 horse-power per annum is added to the power used in agriculture alone, cannot bring the whole to more than 1,000 millions of gallons per diem, or 365,000 millions per annum, which is only a 74th part of the total rainfall with which Providence blesses us on the average of years. In fact, if it were in the power of man to secure the whole of the water required for all uses before the rain was absorbed by the ground, the quantity would be comparatively so small that it could not possibly injuriously interfere with any of those functions which the rain performs, nor in any way affect our general water economy. To make this more clear it may be stated that if there were allotted to each unit of the population 25 gallons of water daily for all purposes, public and private, it would require 9,125 gallons for the year's supply, while one inch of rain falling on an acre of surface, being equal to 22,622 gallons, would afford a year's supply to nearly two and a-half persons.

I have taken pains to set forth these figures, and I lay stress upon them, because they cannot fail to show that, with such a quantity of water at our disposal, it savors of the ridiculous, if not of ingratitude, to complain at one time of scarcity of water for domestic, sanitary and trade purposes, and at another of the extreme wetness of the season. We have only to adopt as a nation the common prudence of household life, of collecting and husbanding our resources, to insure plenty at all times; for, although means and averages do not form with engineers the usual data for water supply, it is quite within the power of man to equalize quantities for his own use by storing excess to compensate for scarcity. We have it in our power, in fact, to provide for every possible want connected with human and animal life, and to become independent of dry years; the only thing required being sufficient reservoir space to provide against a succession of two, or possibly three dry years, when we may have

to deal with minima which may be taken to represent a third less than the quantities we have recorded as averages. Few persons realize, or are prepared to acknowledge, in times of drought, when the poor are paying a penny or two pence a pailful for the first necessary of life, and when cattle are dying in our fields of thirst, that they have by their own neglect thrown aside the most plentiful gift of Providence. They are, on the contrary, disposed to imitate the countryman of the fable who, when the wheels of his wagon stuck deep in the clay, called on Hercules for help instead of putting his shoulder to the work of withdrawal. That which takes place in the water-bearing strata of the earth in the way of storage of the winter's rain for the supply of springs and wells in summer, and that which takes place in the dew-ponds on the high downs of the chalk and oolite in the way of storage of dew as it is deposited from the atmosphere in the warmest weather of summer, are examples we ought to copy.

Yet it is remarkable how years roll past without an effort in this respect; and it is only now because we are suffering from a severe drought, extending more or less to the whole country, and there is a dread of a want of coal, that there is any chance of gaining attention. It is thirty years since I wrote the following words in an article on the "Drainage of Land and the Distribution of Water," in the "Westminster Review," vol. xxxviii., 1842: "Does not Nature, by the machinery of her rivers, her brooks, her springs, point out to art the means of increasing the general salubrity of our island, by providing an outlet for those floods which are peculiar to Britain from its diversity of surface, the prevalence of heavy soils in the valleys, and its sea-bound circumference? The evaporation of water, in the first instance, from the surface of the ocean, and its fall to the land in the form of rain and dew; its re-absorption by the atmosphere; its use by all animal and vegetable bodies; its descent into the porous strata of the earth to be discharged again in the form of springs to the sea, exhibit to man a vast system of perpetual circulation which should incite his emulation to become an instrument for the removal of obstacles which it would appear exist only that his energy may be roused into action." Within the last thirty years agriculture has, perhaps, made greater progress than any other branch of British industry, but nothing, literally nothing, has been done towards the conversion of the evil of excessive wetness into a benefit by provision against scarcity.

Distribution and Present Disposal of the Rainfall.

Having given the large figures I have stated as representing the quantity of rain which reaches the surface, it may be well to trace shortly how Nature disposes of it as it falls. All rain is either absorbed by permeable surfaces, or it is discharged directly by overflow from impermeable surfaces into the rivers, and by the rivers into the sea. In the one case it may be a mistake to speak of its entire absorption by permeable surfaces, for a small proportion is appropriated by vegetation before it is absorbed, and the rest when absorbed descends to the level of the water in the water-bearing strata as soon as supersaturation takes place, to reissue from the surface at the outcrop in the shape of springs, or to raise the subterranean water-bed in the earth. The water upheld in the soil by attraction is gradually given off at the surface by evaporation, and is replaced from beneath as long as the supply lasts The water-level in these water-bearing strata is thus lowered by the outflow of the springs, and by evaporation. In the other case, the rain being wholly resisted where impervious surface exist, and partially so where those surfaces are only thinly covered with soil, passes off without much reduction, the only loss being that proportion which is directly seized by surface vegetation and evaporation. In the six months forming the winter half of the year, from October to March inclusive, floods are more frequent in proportion to the rainfall than in summer, in consequence of the absence, or dormant condition of vegetation, and the reduced extent of evaporation, and owing to the fact that the soil itself is frequently in a wet condition. During this period a considerable proportion of the rain having entered and saturated the permeable soils descends into the earth to do its work of replenishment. In the six months forming the summer half of the year, from April to September exclusive, on the other hand, floods are comparatively few, though they are injurious when they occur, and the quantity of rain penetrating the earth beyond a depth of 3 feet is very small. In-

deed, the water-bearing strata generally receive no appreciable replenishment during the summer; they are nearly wholly dependent for their replenishment on the supersaturation of winter. In some of the extremely open beds, it is true, such as the chalk, the new red sandstone, and the Bagshot sand, the infiltration of the rainfall is rapid, and a heavy rainfall will serve to raise the water-level even in summer, and set the lower springs running, but this is the exception, and not the rule. In fact, the storage of water in the earth does not accumulate until the winter rains have produced supersaturation. In a well that I carefully watched during the wet winter of 1872–73, I found the water stood on the 1st of January, 1873, at exactly the same height as on the first of the preceding July; while from the beginning of the year 1873 to the 1st of the following May, the water had gradually risen 7 feet 10 inches higher than it was on the 1st of January. A wet summer has very little effect in increasing the subterranean supply, but it has the advantage of restoring the water upheld by attraction, and thereby of lessening the demand on the water stored beneath, which would otherwise rise and lower the level of its bed. When great rainfalls occur in summer, that proportion which is not absorbed passes into the rivers to swell and increase their volume without any apparent corresponding advantage beyond raising for a short time their perennial flow. It may be stated that the proportion of rain required to maintain the natural flow of our rivers during the summer and dry weather periods of the year is about one-eighth of the average mean rainfall, or 4 inches over the whole of the river watersheds. Of course, in different rivers this will vary according to the amount of rainfall, the inclination of the surface, and the character of the soil. The quantity or proportion of rain which finds its way over the surface to be discharged by the rivers to the sea without entering the ground at all, taking the west and east side together, is at least 15 inches, or nearly four times the perennial flow, and nearly half the average mean rainfall. This quantity will necessarily also vary very considerably, according to the depth of rain and the character of the contributing surfaces. In the eastern and midland parts of England the mean depth of water run off in the shape of floods and freshets will barely reach 6 inches, while in the west, including the higher lands of the eastern counties of Wales, the Lake district and the northern counties, the mean may be stated to be 20 inches. Mr. Bateman showed in his evidence before the Metropolitan Water Supply Commission that it exceeded 40 out of 60 inches in the high grounds of Wales, while Messrs. Hemans and Hassard considered that it reached 65 out of 80 inches in the Lake district. I may mention, as an illustration of how remarkably quickly the rainfall is discharged, that although 44 inches of rain had fallen in the Lake district between the 1st of October, 1872, and the end of January, 1873, I found when at Kendal on the 19th of February (1873) the water of the Kent to be remarkably low, and was informed by the borough surveyor that it was 14 inches below ordinary summer level, and when crossing Windermere lake the day previous (18th Feb., 1873) the ferryman assured me that the height of the water approximated ordinary summer level. The present condition of drought (July, 1874) prevalent throughout the whole country, is as much felt in the Lake district as in any other; and I may mention as a contrast to the 44 inches which fell between 1st October, 1872, and 31st January, 1873, that $17\frac{3}{4}$ inches of rain only fell in the same period ending January, 1874.

It will be remembered that in the winter of 1872–3 the rainfall so far exceeded the average that it was thought wise to offer up prayers in our churches for drier weather. In the winter last past the rainfall has been very considerably *below* the average, though not so much less as in the previous winter it had been *above* the average. In the eastern counties—the driest part of the country—for instance, the quantity of rain that fell in the six winter months from October, 1872, to March, 1873, inclusive, was $21\frac{1}{2}$ inches, while the amount due to the same period last winter, 1873–4, only reached 9 inches. The mean of many years is somewhat above 13 inches.

Comparing this mean with the rainfalls of the last six winters (in the eastern counties) we shall see that, although we have had within that period two singularly dry years, the fall of this last winter was less than any.

	1867–8.	1868–9.	1869–70.	1870–1.	1871–2.	1872–3.	1873–4.
Rainfall—October to March inclusive.....	11.90	18.00	15.72	15.35	13.25	21.55	9.

In order that the quantity of water discharged on an average of years from several different descriptions of gathering grounds may be appreciated, I will give from the late Mr. Beardmore's evidence before the Water Supply Commission, 1867, the outflow of the Lea and the Thames on the east of the Lias, and from some other authorities the discharges from river areas on the older geological formations.

River Basin.	Drainage Area.	Rainfall.	Discharge.	Year.	Authority.
	Sq. Miles.	Inches.	Inches.		
England—East of Lias:				Average.	
Thames	3,670	26.08	7.83	1850 to 1868.	Mr. N. Beardmore.
Lea	444	25.60	6.54	Ditto.	Ditto.
England—West of Lias:					
Rivington Pike	16¼	45.70	35.50	1850 to 1867.	Water Supply Commission.
Mersey and Ribble	2,207	39.00	20.00	Average.	Rivers Pollution Commission.
Scotland:					
Loch Katrine	71	103 30	81 70	1854.	Beardmore's Hydrology.
Loch Lubnaig	70	66 70	50 96	1847.	Ditto.
Greenock	8	60.00	41.00	1827-8.	Ditto.

Storm or Surplus Waters to be Stored.

It is the surplus, or waste waters, which I compute at a mean of 15 inches, or rather so much of it as is not already appropriated, that may be stored with advantage. The quantity already appropriated is comparatively small; and though several large towns have been supplied by this means, the quantity so appropriated in those localities is fully compensated by the water of underdrainage discharged elsewhere, consisting for the most part of rain which, before drainage, had been upheld in the soil until it was evaporated. By many persons it has been supposed that the effect of underdrainage has been to diminish the water supply rather than increase it—I presume on the supposition that the springs would be weakened by the loss of that proportion of the rain which would be upheld in the 3 or 4 feet of surface soil which alone is affected by drainage. A little reflection will, however, satisfy every one that this cannot be the case, inasmuch as water cannot run out of the drains until the subsoil is filled with water up to the level of the drains, and the soil between the drains and the surface is in a state of supersaturation. When, in winter, this condition has been reached, a large proportion of the rainfall is discharged from the underdrains within 24 hours of its reaching the surface, if the surface soil be properly cultivated and rendered absorbent. In the summer there is little or no dischage from the underdrains of clay lands, though in many instances a never ceasing and copious discharge is obtained from the draining of surcharged free soils. There is no doubt that with extension of under-drainage an improvement of our rivers and watercourses has necessarily been effected, and that the water from the underdrains, when discharged, as well as that which overflows the surface, is carried down into the valleys with greater rapidi y than before. The result is a considerable increase in the aggregate, though, for the most part, the quantity obtained is due to the winter's discharge and not to that of the summer. Few would suppose that the quantity of land already drained, which is assumed to be three millions of acres, would furnish an effluent water equal in quantity to nearly half the water supply required by the whole population of England and Wales, for domestic, trade and public purposes. It is nevertheless true, inasmuch as the discharged water amounts to a mean of 150,000 millions of gallons on an average of years. The practical value of this fact will be acknowledged when it is understood that even in dry years the under-drainage water from an acre of land will be sufficient to supply four persons all the year round with 25 gallons each per diem.

At present we are content to draw the water out of the land, and instead of turning it to account, allow it to increase the evil of surface floods by its discharge into the valleys at times when they may be under water; and this we are doing when water has an increasing value as a source of motive power in consequence of the advancing price of coal. Allowing the new water of under-drainage to compensate for that proportion of the surface water that is already utilized, it may be assumed with

certainty that there are at least 20 millions of acres out of the 37,324,883 acres, which in the aggregate do throw off a mean of as much as 25 inches of the rainfall which may be stored for useful application. This area of 20 millions, representing rather more than half the superficial extent of England and Wales, would consist of the higher grounds of both divisions of the country, and would in the aggregate deliver its surplus waters at an available mean height of at least 150 feet. To reduce this to horse-power by the ordinary calculation would be an easy matter, but I am afraid that the result would not be considered tangible. I am therefore content at this moment to assert that a power equal to at least *half* that obtained from the use of coal might be secured from this source alone. At present it is estimated that 30 millions of tons of coals are used annually for steam power in locomotion and manufactures, and that the power obtained is 1,905,700 horse-power.

To bring the value of the power we possess in the shape of surplus waters better home to the mind in a national point of view, it should be remembered that the chief manufacturing towns are located in the western and northern counties, where the prevailing height of surface is the greatest, and where the quantity of rain and the number of wet days both increase proportionately to height; so that the utilization of the rainfall there becomes a tangible object, and free from those doubts which might appertain to the eastern side of the country. It was owing, no doubt, to the presence and plentitude of water that first led manufacturers to select the western side of England as the best suited for the objects they had in view, and to erect mills in the higher valleys, although the existence of coal on that side of the country has done more than anything else to retain the manufacturing districts where they are. Now that we have had a practical warning of the diminishing supply of coal by an increase in its cost, I think it will be conceded that it is not at all improbable that those branches of trade which are dependent on the use of motive power, may, before long, revert to the use of water in the place of steam. It was only a short time back that three several schemes for the supply of water to the metropolis were presented to the public, of which two were to gain their supply from Wales, and the third from the Lake district. Since that time seasons and circumstances have led several of the towns in the north and west of England to congratulate themselves on the circumstance that these proposals were not successful, and when we see what has been done at Greenock and other places in utilizing the water derived from the drainage of wide areas of land, it will be acknowledged that the country at large will be the gainer by the retention in the manufacturing districts of all the water placed at their disposal.

Greenock, an Illustration of the Profitable Use of Surplus Waters.

No instance could be more apposite to this remark than that afforded at Greenock. There the contributing area of Shaw's Waterworks, which was estimated by Mr. Thom, the engineer, to supply 553,930,000 cubic feet of water per annum, of which the town was to take 18¼ millions, and two lines of mills the remainder, has actually supplied 650,000,000 cubic feet in the year. The Provost of Greenock writes me as follows: "They did not fail us in either 1864, 1868 or 1870; but they did fail to supply all our demands upon them in 1869—the driest year we have had during 40 years. They could have supplied even in that year Mr. Thom's estimate of 554,000,000 cubic feet. The drainage area of the Shaw's works is far from being exhausted; but our storage being limited, we have to waste largely in winter. In 1869 we had sufficient water for domestic purposes, but for some weeks we could not maintain the full supply of 11,000,000 gallons per day for mill power. The Shaw's works cost the original proprietors from first to last about £80,000; and the town is buying them for £170,000. The total supply they give is as above; but, as I have stated, were we to increase our storage, the works would yield a great deal more water."

The Condition of the Thames in Times of Drought.

Before leaving this view of the subject, let me point out that one of the great advantages of storing winter waters, beyond that of turning them to profit for the supply of the population for domestic, trade and sanitary purposes, and as a motive power as coals become dearer, will be their use in maintaining with regularity the summer flow of rivers at a height above the minimum flow of dry seasons. The advan-

tage of extending the principle of compensation—beyond that of merely returning to rivers the same quantity of water that may be taken out of them—to the supply of such a quantity as will enlarge their flow when reduced below a certain quantity, may be illustrated by the condition of the Thames in extreme droughts. The quantity of water flowing just above Kingston, and above the intakes of the water companies, has on several occasions been reduced to 350,000,000 gallons per diem, although engineers generally agree in the opinion that the flow should never be less than 500,000,000 gallons. This deficient quantity is again reduced by that abstracted by the Metropolitan water companies. By the evidence given by Mr. J. Thornhill Harrison before the Water Supply Commission in 1867 (which should be studied by all who are interested in the subject), it appears that on 185 days in the years 1858 and 1859, the river flow was less than 500,000,000 of gallons—that in point of fact there were 34 days when the flow was reduced to 350,000,000—and it would be on such occasions that the stored surplus waters of winter might be used with excellent effect. I need not point out how beneficially the same principle would apply to smaller rivers, whose beds are nearly dried up at certain seasons of the year.

Storage to be adopted for Villages and Rural Districts.

Though the storage of water must commend itself to most people as an object of great importance, the subject would hardly be appropriate if it were limited to generalisms, and were I not to show how it may be usefully applied in rural districts for the village and the farm. I need not recur to that with which we are all familiar—viz., that dry seasons frequently prevail in which the laboring poor of our villages and the stock of our farms have been deprived of their full supply of water, and have had to resort to surface ponds and other means of supply, the quality of which has been as filthy as it could well be. The present summer affords a telling illustration of the miseries of a drought. What would now have been the condition of the surface springs and wells had not the last winter followed an extremely wet one, which had raised the sources of all supply, it is difficult to say, for the misery among the poor and the difficulty of supplying stock are both being felt in an extreme degree in spite of frequent storms. When farming on the hills of Hertfordshire I have myself had to cart the whole of the water used by my horses, cattle, and sheep a distance of 2 miles, while my poorer neighbors have had to pay by the pail for the water they consumed. When the poor are paying by the pail on such occasions, it should be understood that the inhabitants of towns are supplied at all times and in the upper stories of their houses at from 6d. to 2s. per 1,000 gallons, whereas the amount paid by the poor villager, when 1d. is charged for a pailful of 2 gallons, is 42s. per 1,000 gallons. Many are the farms and villages with which we are all acquainted, where the want of water is a most serious item, and it is not many years since that the loss in sheep was very great in some districts. I remember, when on the Romney Marsh, hearing of a large number being lost entirely for the want of water. Now, with mutton at from 10d. to 1s. per lb. this ought not to be, particularly if I am correct in stating that even in the driest winter the excess that exists beyond what is wanted distinctly proves a capability of storage which might easily be brought to bear. The storage of water in small quantities is necessarily an expensive proceeding, for open shallow ponds and reservoirs, encouraging, as they do, the growth and decay of vegetable matters, are to be avoided if possible, and either deep open reservoirs, or covered tanks should be resorted to. The use of concrete as material for the construction of underground tanks, however, reduces the cost very considerably, and will, I hope, help greatly their introduction in rural places. The commonest lime, properly slaked and mixed in due proportions with clean gravel and sand, or with burnt clay ballast, or even sifted chalk itself, if faced with Portland cement, will make admirable tanks. Selenitic cement will probably be found on trial to be equally applicable as a watertight facing, using perhaps twice as much more than Portland cement, which can be done without increase of cost, for it is to be bought at half the price. In using common lime—*i. e.*, the lime of the locality—for the main body of concrete, great pains must be taken to have it thoroughly slaked before mixture, for if this is not done, the lime will afterwards slake in the wall and cause fracture, and fracture means

leakage. It is a great pity that the Government does not institute an inquiry into what has already been done, and authorize actual trials to be made, which would set at rest all doubts as to the capability and cost of making water-tight tanks suitable to different localities and physical conditions. Many valuable details of past experience might be collected if competent persons were engaged to visit different parts of the kingdom and see what has been done, with a view to communicate information to sanitary authori ies as to construction and cost. At present they will do nothing for fear of the cost. No money could be better spent, and a few hundred pounds is all that is wanted for the purpose. In some parts of the chalk districts underground tanks have been made by burrowing into the earth and making a chamber or cavern (with an opening at the top for the removal of the soil), which, being lined inside with a thin covering of cement, is made perfectly water tight. Thus the most capacious tanks may be provided for comparatively a few pounds, and districts may be supplied with water which are now destitute of it. This mode of constructing tanks might also be adopted in other geological formations besides the chalk, where the water level is low in the earth with a considerable depth of drained subsoil above it within which to make the "cavern tank." I need hardly say that such a recep'acle for water can only be adopted where the soil is naturally drained, and where there is no pressure of external subsoil water. No dwelling or set of buildings, of which the roofs are slate or tile, should be without its tank, unless the occupants are otherwise abundantly supplied. There are few places in England, and certainly none in Wales, in which 20 inches of rain may not be collected with certainty, even in the driest year. Taking an ordinary middle-class house in a village, with stabling and outbuildings, the space of ground covered by the roofs will frequently reach 10 poles; while the space covered by a farm laborer's cottage and outbuilding will be 2½ poles. Assuming that the roof is slate, and the water dripping from it is properly caught by eave-troughing and conducted by down-pipes and impervious drain-pipes into a water-tight tank, sufficiently capacious to prevent overflow under any circumstances, and that by this method 20 inches of water from rain and dew are collected in the course of the year, the private house will have the command of 28,280 gallons, and the cottage 7,070 gallons in a year. To make it clear that this quantity of water can generally be obtained, it should be stated that the proportion lost by evaporation, etc., from a slate covering will not exceed one-sixth of the total quantity of rainfall with the deposition of dew added. A tank 16 feet long and 10 feet wide will hold 1,000 gallons in every foot of depth, and where the water is not wanted for drinking it need not be covered except with a common boarded floating roof of half-inch boards fastened together. This floating roof keeps the water clean, and reduces loss by evaporation. The supply of water to villages, however, should not be dependent upon individual action altogether, for the occupiers themselves are powerless, and cottage owners as a rule are not very liberally disposed in the provision of this necessary of life. There should be some public supply, to render villagers independent of their landlords. Where there exist rivers or streams of pure water near at hand, or where there is a subterranean water-bed easily reached by sinking wells down to it, it is needless to think of storage, but so long as there are large numbers of small communities with rating values so low as to negative the power to charge any large outlay upon them, it behooves us to consider with the utmost care any plan which will enable us to secure a sufficient supply of pure water at a cheap cost. In villages it is unnecessary to aim at the supply of from 20 to 25 gallons a head. Two gallons of water per head per diem is as much as is at present consumed in the majority of villages, and 10 gallons are quite ample. To supply 10 gallons a head should not be a difficult matter; though in cases where there is no land that has been artificially underdrained near at hand allowing of the under-drainage water being utilized, or where there is no other means of collecting surface water, it may be absolutely necessary to combine several villages, and by a properly devised system provide for the whole. Much may be done by insisting that cottage owners should provide each cottage with such a tank as I have spoken of, or the share of a tank with other tenants, and by the addition of a common tank to hold a month's supply for the whole village the object might be secured at a fair

cost. I have lately contrived a tank-filter, to be placed *inside* the tank, through which the water passes as it is drawn up by the pump. It is made in earthenware, and sold by Messrs, Doulton & Co. Under propitious circumstances surface waters may be collected in winter for summer use in open reservoirs, but they should never be less than 7½ feet deep in the clear. The water may be delivered in the village street from these reservoirs at from 20s. to 25s. per person, including purchase of land for the reservoir, iron pipes, stand pipes, and taps. Assuming that the money required be borrowed and paid off in thirty years by instalments not exceeding in amount 5 per cent. on the outlay, the result would be a charge of about 1s. or 1s. 3d. per person per annum. I am satisfied, however, that nothing of a tangible character will be done until it can be shown by evidence of actual experience and positive experiments, that reservoirs and tanks can be (comparatively) cheaply made with reference to local features; and that landowners having life interests in property in the neighborhood of villages may collect surface water and construct reservoirs upon their estate to hold it, *by means of borrowed money*, which may be charged upon the property and repaid by instalments. The landowner might then turn water-contractor and supply the neighboring district at an agreed price sufficient to repay him his outlay with some slight profit. But to do this, legal powers are necessary, not only to sanction a tenant for life becoming a water contractor in the way proposed, but to enable sanitary authorities to enter into such an agreement as will make the recipients of the water pay for it within such a pre-determined term of years as will liquidate the cost of the necessary works without pressing hardly upon any one. There can be no irreconcilable reason why such an arrangement should not be made and the cost of the work charged upon the estates on which the water is collected, for the reversionary interest would be benefited by the ultimate possession of a water-property from which a considerable income would be forthcoming after the original outlay is liquidated.

Field Storage.

I have pointed out on more than one occasion how on clay land farms, where thorough drainage has been adopted or is required, the water of under-drainage may be preserved, sometimes in ponds, but more frequently in underground tanks, for the use of the cattle of the farm and for steam cultivation. The facilities with which such provision can be made have not been sufficiently acknowledged. A 10 horse-power engine requires for the cultivation of an acre of land from 100 to 125 gallons of water, and an underground tank capable of holding 2,500 gallons would, therefore, be sufficient for the cultivation of 20 acres. For this quantity the tank should be 8 feet wide, 10 feet long, and 5 feet below the level of the drains, and if concrete were used the cost need not exceed £15 or £16. This tank might be placed in any position convenient for the steam-plough or cultivator, and none will deny the great value of such a supply of water wherever steam is employed in the cultivation of land situated on hills where water is now difficult to get.

Before concluding I must again revert to the more comprehensive view of the subject with which I started. I am fully impressed with the fact that each case of water supply, as well as any other local improvement, must be dealt with upon its own merits; but, to secure any action at all, there must be general obligations in the form of a legal code to be *enforced* by central authority. Permissive laws are more pleasant to British subjects than compulsory ones, but they are absolutely useless in such matters as village water supply. I am quite sure that so long as it is optional with village communities to adopt or reject any proposal for an improved supply in respect of the first essential of life—water—very little will be done. I cannot expect, at a time when the agricultural interest are jealously watching the question of local rating, with a full determination to bring its relations to national taxation to a point, that the opinion I am about to express will be unhesitatingly adopted—vis.: that legislative powers are wanted which shall extend the proper distribution of water to the whole country. From what appears to me to be the mistaken view of the Government, the country has been apportioned into districts for sanitary purposes which are perfectly incompatible with a right treatment of the subjects in view. It may flatter our local prejudices to leave the management of such matters in the hands of boards of guardians as "the rural sanitary authority," and in those of boards of health as "the

urban sanitary authority," but it will not be until some superior presiding authority have jurisdiction over watershed districts, that drainage, sewerage, water supply, and some other kindred objects can be effectually and economically treated. Towns have been sewered without caring what becomes of the sewage; lands have been drained without providing proper outfalls; districts have been improved by trunk drainage without regard to neighboring districts of the same watersheds; and thus one community, or part of a watershed, has been freed of sewage or water, while another has been injured by the discharged liquid. In fact, it would almost seem to be the object of our Legislature, in sanitary matters, first to encourage us to do wrong, then to point out the error we have committed, and, finally, to leave us without any power of rectification. It cannot be expected, while this course of action continues, that any *general* scheme for the storage of water should receive attention, but we may fairly anticipate partial action as the result of recurring droughts like the present one.

REPORT OF EXPERIMENTS UPON VARIOUS AMERICAN BUILDING STONES.

By Q. A. GILLMORE.

The majority of the stones experimented upon were delivered from the quarries in the form of true cubes, measuring 2 in. each way; while some had to be cut to that shape at Fort Tompkins. Generally speaking, the stones were quite true and regular in shape. To distribute the pressure more evenly over the whole surface of the stone, each cube was placed between two cushions of soft pine wood, measuring $2'' \times 2'' \times \frac{3}{8}''$; one of them on the top of the cube, and the other at its bottom.

This arrangement also caused the pressure to act more gradually. The wooden cushions, becoming much indurated by the effects of the pressure, to some extent took the place of mortar, which would be used in actual building.

For iron and wood, Hodgkinson has shown that trial specimens should be at least $1\frac{1}{2}$ times as high as the width of bed; but as stone, except when used in columns, is always made of less height than bed, the cubical form of specimens adopted for the experiments affords sufficient security against angular breakage.

The apparatus used for testing was a hydrostatic press, known as the Hoe press.

The stone to be tested was placed between two pieces of pine wood, as already mentioned, and gradually raised until it touches the lower face of the beam, or cross-head. By continued pumping, the pressure is increased until the stone crushes, and the amount of pressure noted by means of the gauges.

The Report was accompanied by descriptions and diagrams of the press not included above.

The press is supplied with two gauges, one indicating the pressure up to 100,000 lbs., the other to only 5,000 lbs. Both are connected by pipes with the lower end of the cylinder of the ram. Both gauges may be used simultaneously until the capacity of the 55,000 lb. gauge is exhausted, when its connection with the cylinder is shut off by a little valve worked by a hand-wheel. Generally, in testing stones, the lighter gauge is not used.

To check the working of the 100,000 lb. gauge next to the press, another gauge of a similar capacity was employed as a test-gauge. It is attached to the connecting-pipe, near to the pump. These gauges were manufactured in the city of New York, on a modified arrangement of Bourdon's principle.

The 100,000 lb. gauge, like the two others, has a dial-face, traversed by two hands of unequal length. One of these is moved directly by the power of the press; the other (shorter) hand is simply carried along by means of a little projecting pin on the back of the longer hand, or power-needle. The latter returns to the zero-point as soon as the pressure ceases, leaving the shorter hand at the maximum reached on the scale. The record can thus easily be read off, after which the record-needle is pushed back to zero-point in readiness for another trial.

The graduations on the dial-plate of the gauge are fixed by comparison with an air manometer, or with another Bourdon gauge, known to be correctly graduated; and the correctness of the gauge is guaranteed by the manufacturer. But it is, of course, de-

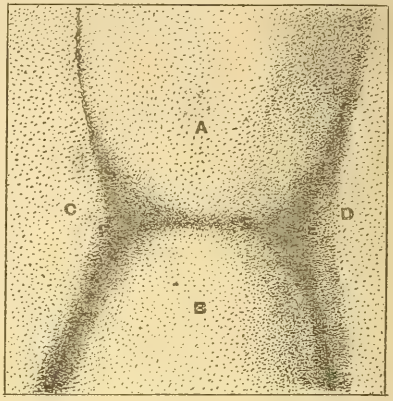
sirable to be otherwise well assured of the accuracy of the records obtained. For the series of experiments herein spoken of, a check was obtained, as already mentioned, by means of another 100,000-lbs. gauge near the pump, so that a test between these two gauges once established, either one can be taken off when rough work is to be done (the most sensitive one always), and the other used, and then both tested again. By this means there can be no change that would escape the notice of an attentive operator, and the actual power used can at any time be tested in full by the application of either gauge to a hydraulic press having a lever accompaniment.

The weight of the movable part of the press is nearly 780 lbs., which, with its own friction, amounts to 800 lbs., nearly. This is to be subtracted from the "strength of specimen," or 200 lbs. from the strength per square inch. Much dispute has existed about the friction of the hydrostatic press when performing heavy duty. Rankine made some rough experiments, which caused him to estimate the friction at 10 per cent. I. Hicks, civil engineer, of Bolton, England, found, by very careful and long-continued trials, made regardless of expense, that the friction varies with the diameter of the ram, and that it is very small and very certain. By his trials the friction of the ram used in the experiments herein discussed (the cylinder being $4\frac{1}{2}$ in. diameter), would amount to $\frac{3}{10}$ per cent. only, or say 1 per cent. This could and should be tested upon the individual ram; but, without special and costly appliances, it will have to be got at indirectly, and, therefore, slowly.

The Breakage of Stone.

Considering the infinitely varied composition and character of all kinds of rock, it may be said that no material is less calculated to permit the establishment of special laws by a general form of breakage. It may be safely assumed, however, that more numerous and extended experiments, carefully and patiently conducted, will ultimately lead to the development of certain general laws relating to the behavior of stones under pressure, a knowledge of which will be most useful to the engineer and builder.

Homogeneous stones seem, in most cases, to break in the following manner (see diagram): The forms of fragments *a* and *b* are approximately either conical or pyramidal, according as the stone is friable and of obviously granular structure, like sandstone and a few kinds of marble and granite, or compact, such as the true limestones and most marbles and granites. The more or less disk-shaped pieces, *c* and *d*, are detached from the sides of the cube with a sort of explosion, flying off in a more or less intact condition. In *e* and *f*, the stone



is generally found crushed and ground to powder by the attrition of the larger fragments. Of course this general result, or law, is modified by the nature and quality of the "grain" in the stone, and those other causes of irregularity which leave no two cubes of the same strength and condition, although they may have been cut directly apart from each other.

This form of breakage occurs also in non-homogeneous stones broken "on bed;" but it must be remembered that here the modification must be taken into account which "grain" produces as against homogeneity, rendering the object liable to split in rectangular fragments. This frequently lengthens the cone or pyramid in stones "on bed," and causes those set "on edge" to actually split in rectangular disks; the style of splitting being, of course, irregularly modified for different specimens. Sand-cracks, etc., in stones, have also their influence in directing the pressure, and even the difficulty of determining the "bed" in some stones, after being cut, may be a source of errors.

The two strangest cases of abnormal breakage occurred in the United States Quarry limestone (Nos. 29 and 30 of table), the first of which, "on bed," threw off a couple of thin fragments, and then exploded; the balance of the stone being scattered about in minute particles. The second,

Crushing-strength of granites in two-inch cubes.

Number.	Kind.	Locality.	Position.	Cracked.	Strength of specimen.	Strength per square inch.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.
				Pounds	Pounds.	Pounds.		Pounds.		
1	Blue	Staten Island, N. Y.	On bed	24,000	89,000	22,250	2.861	178 8	Absorption too slow to be taken while weighing.	Cracked before bursting.
2		Fox Island, Me.			59,500	14,875	2.631	164 1		Burst suddenly.
3		Dix Island, Me.			60,000	15,000	2.635	166.5		Do.
4	Dark	Quincy, Mass.		19,500	71,000	17,750	2.660	166.2		Cracked before bursting.
5	Light	do		18,000	59,000	14,750	2.695	168.7		Do.
6		Tarrytown, Westchester County, N. Y.	On bed	22,000	73,000	18,250	2.655	162.2		Do.
7	Flagging	North River, N. Y.			53,700	13,425	2.690	168 1		Broke suddenly without cracking.
8	Old Quarry	Westerly, Washington County, R. I.			71,000	17,750	2.646	165.6		Do.
9	do	do			69,000	17 250	2.646	165 6		Do.
10		Millstone Point, Conn.			64,750	16.187	2 706	168.7		Do.
11		do			75,000	18,750	2.706	168 7		Do.
12		Sprucehead, Me.			54,000	13 500	2 750	171.9		Do.
13		do			70,000	17,500	2 750	171 9		Do.
14		Hewitt's Island, Me.			57.500	14,375	2 634	164 6		Do.
15		do			60,250	15.062	2.634	164 6		Do.
16	Up river	Richmond, Va.			85,000	21.250				Do.
17	do	do			80,000	20,000				Do.
18		Greenwich, Conn.			45,200	11,300	2.835	177.2		Do.
19		do			46,800	11,700	2.835	177.2		Do.
20	Niantic river	New London, Conn.			50,000	12 500	2.660	166 25		Do.
21	do	do	On edge		56,700	14,175	2 660	166 25		Do.
22		Fox Island, Me	On bed		60.250	15,062	2 660	166 3		Do.
23		do			46,800	11,700	2 660	166 3		Do.
24		Vinalhaven, Me			52.600	13,150	2.720	170.0		Do.
25		do			67,000	16,750	2.720	170.0		Do.
26	Harlem stone	Morrisania, Westchester County, N. Y.			63,200	15,800	2.720	170.0		Do.
27	Tombstone	Sharkey's Quarry, Me.			88.500	22,125	2.720	170.0		Do.
28	do	do			83.500	20,875	2.720	170.0		Do.
29		Richmond, Va			61.250	16,063	2.727	170 5		Do.
30		Cape Ann, Mass.	On bed		59.750	12,423				Do.
31		do	do		78,000	19,500				Do.
32	Porter's rock	Mystic River, Conn.	do		72.500	18,125	2.630	164.4		Do.
33	do	do	On edge		89,000	22,250	2 630	164.4		Do.
34	Gray	Westerly, R. I.	On bed		58,750	14,687	2.670	166 9		Do.
35	do	do	On edge		59.750	11.937	2 670	166.9		Do.
36	do	Richmond, Va.	On bed		56,400	14,100	2.630	164 4	1-348	Do.
37	do	do	do		55.500	13,875	2.630	164.4	1-348	Do.
38	do	New Haven, Conn.	On edge	29,000	31,000	7,750	2 600	162.5	1-230	Waxy-looking, having a resinous lustre.
39	do	do	On bed		38,000	9,500	2.600	162 5	1-230	Burst suddenly.
40	do	Stony Creek, Conn.	do		60,000	15,000	2.645	165.4	1-401	Do.

Crushing-strength of granites in two-inch cubes.—Continued.

Number.	Kind.	Locality.	Position.	Cracked.	Strength of specimen	Strength per square inch.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.
				Pounds.	Pounds	Pounds		Pounds		
41	Gray	Stony Creek, Conn	On edge		67,000	16,750	2 645	165 4	1-201	Burst suddenly.
42	do	do	On bed		63,000	15,750	2.645	165 4	1-201	Do.
43	do	Fall River, Mass	do		63,750	15,937	2.635	165.	1-216	Do.
44	do	do	On edge	33,000	37,000	9,250	2.635	165.	1-216	First split vertically.
45	Rose	Niantic, Conn	On bed		38,200	9,550	2.600	162 5	1-704	Burst suddenly; pores supposed filled with red pigment.
46	Gray	do	do		37,800	9,450	2 580	161.2	1-254	Burst suddenly.
47	Gneiss	Sachemshead Quarry, Conn	On edge		63,750	15,937	2.620	163.7	1-162	Do.
48	do	do	On bed		56,000	14,000	2 620	163.7	1-162	Do.
49	Gray	Hurricane Island, Me	do	33,000	57,700	14,425	2.670	166.9	.....	
50	do	do	On edge		59,750	14,937	2 670	166.9	.....	Burst suddenly.
51	do	do	On bed		44,000	11,000	2.670	166 9	.....	Split off considerably before bursting.
52	Dark, soft-looking	Madison Avenue, N Y	do		45.000	11,250	2 920	182 5	0	Probably contains an unusual quantity of [iron.
53	do	do	On edge		50,000	12,500	2.920	182.5	0	
54	Gray	Port Deposit, Md	On bed		79,000	19,750	2.720	170.	0	Coarse: strongly dashed with black.
55	do	do	On edge	33,000	52,400	13,100	2 720	170.	0	Do.
56	do	do	On bed		66,000	16,500	2 720	170.	0	Do.
57	do	do	do		60,000	15,000	2 720	170.	0	Burst suddenly.
58	do	Garrison's, North River, N. Y	On edge	48,000	49,000	12,250	2.580	161.3	1-167	
59	do	do	On bed	51,000	53,500	13,370	2.580	161.3	1-167	
60	do	Palmer Quarry, Me	do	41,000	46,000	11,500	2.590	161.9	1-150	
61	do	do	On edge	58,000	66,000	16,500	2 590	161 9	1-150	
62	do	Rockport, Mass	On bed		65,200	16,300	2.610	163.2	1-152	
63	do	do	On edge	36,000	79,000	19,750	2.610	163 2	1-152	
64	Dark	Du Luth, Min	On bed		71,000	17,750	2 780	173 7	1-711	Syenitic: or, perhaps, trap-rock.
65	do	do	do		76,000	19,000	2 800	175.	0	
66	do	do	do		67,300	16,825	2.800	175.	0	Scant.
67	Purplish	Huron Island, Mich	do		72,500	18,125	2.630	164.4	1-659	
68	Grayish-rose	do	do		82,600	20,650	2 66	166 2	1-600	
69	do	do	On edge		57,700	14,425	2.62	163.7	1-363	Soaked a week for absorption.
70	Grayish	Chaumont Bay, N. Y	On bed		91,000	22,750	2 65	165.	1-355	Do.
71	do	do	do		64,200	16,050	2 65	165	1-350	Do.
72	do	do	do		70,000	17,500	2.66	166 2	1-557	
73	Dark	Du Luth, Minn	do		68,000	17,000	(*)	(*)	(*)	
74	do	do	On edge		68,750	17,187	(*)	(*)	(*)	
75	Light	Saint Cloud, Stearns County, Minn	On bed		64,060	16.000	2.69	168 2	1-239	
76	do	do	On edge		74,000	18,500	2 69	168.2	1-239	
77	Bluish-gray	Keene, Cheshire County, N. H	On bed		41,000	10.375	2.656	166	1-300	Used in inside of new capitol, Albany, N.Y.
78	do	do	do		51,500	12,875	2.656	166.	1-300	

Crushing-strength of limestones in two-inch cubes.

1	Glen's Falls...	Glen's Falls, Warren County, N. Y.....	On bed ..	.....	45,900	11.475	2 700	168.8	.....	All the stones named below, burst without cracking, except those noted to the contrary.
2	..do	... do	On edge .	... .	43,000	10,750	2.700	168 8	.....	
3	Lake	Lake Champlain, N. Y.....	On bed ..	.....	100,600	25,600	2.75	171.9	.... ..	
4	....do	....do.....	On edge .	60,000	86,000	21,500	2 75	171.9	.....	
5	....	Canajoharie, Montgomery County, N Y.	On bed ..	70,600	82,800	20,700	2.685	169 8	.....	
6	....	....do	On edge .	70,000	77 000	19,250	2 685	169.8	.....	
7	North River....	Kingston, N. Y.....	On bed ..	40,000	55,600	13,900	2.69	168 2	.....	
8	....do.....	.. do.....	On edge .	.....	44,200	11,050	2 69	168.2	.....	
9	....	Garrison's Station, N. Y.....	On bed ..	.....	74,000	18,500	2 635	164.7	.....	
10	.....	....do.....	On edge .	.....	73,100	18,275	2.635	164.7	.....	
11	....	....do.....	On bed ..	.....	71,000	17,750	2.62	163.7	.....	
12	....	....do	....do....	.....	71,0 0	17,750	2 616	163.5	.....	
13	....	....do.....	.. .do....	.....	75,100	18,775	2.616	163.5	.....	
14	White	Marblehead, Ohio	....do....	....	45.000	11,250	2.4	150.	1–30	
15	... do....	....do.....	....do....	.....	42.800	10,700	2.4	150.	1–33	
16	....do	....do.....	....do....	.....	50,400	12,600	2.48	155.	1–33	
17	....do.....	Joliet, Ill.....	....do....	.....	51,100	12,775	2.54	158.8	1–51	
18	....do.....	.. do.....	... do....	.....	67,600	16,900	2 60	162.5	1–139	
19	....do.....	....do.....	....do....	... .	58,600	14,650	2.54	158 8	1–91	
20	Drab	Lime Island, Mich.....	....do....	.....	72,000	18,000	2.50	156 3	1–76	
21	....do.	....do...	....do....	.....	100,000	25,000	2.58	161.2	1–139	
22	....do	....do.....	....do....	.....	61,700	15,425	2.551	159.4	1–56	
23	....do.....	Marquette, Mich.....	On edge .	.....	32,200	8,050	2.34	146.3	1–23	Rather a clay stone.
24	....do	....do.....	On bed ..	.....	31,300	7,825	2.34	146.3	1–23	
25	....do	....do	On edge .	.....	30,400	7,600	2.34	46.3	1–23	
26	Bluish-Drab,...	Big Sturgeon Bay, Wis.....	On bed ..	.....	86,000	21,500	2 78	173.8	1–399	A remarkably solid, stable stone.
27	....do....	....do	On edge .	.....	66,750	16,687	2 75	171.9	1–678	
28	....do	Le ont Quarry, Cook County, Ill.....	On bed ..	.....	48,000	12,000	2.645	165 3	1–89	
29	....do.....	....do	On edge .	.....	56 000	14,000	2.645	165 3	1–89	
30	Dark	Bardstown, Ky.....	On bed ..	.....	65,000	16,250	2.67	166.9	1–80	Used for Louisville and Portland Canal.
31	....do.... .. .	....do.....	On edge .	.....	60,000	15,000	2 67	166.9	1–80	Do.
32	White	Joliet, Ill.....	On bed ..	.....	45,000	11,250	2.55	159.3	1–35	Specimens scant in measure, and not so good as Nos. 17 and 18 of same.
33	....do	... do.....	On edge .	.....	28,200	7.050	2.55	159.3	1–35	Do.
34	Dark-Drab.....	Billingsville, Cooper County, Mo	On bed ..	.....	26,600	6,650	2.32	145.	1–23	
35	....do	....do.....	On edge .	.....	29,000	7,250	2.32	145.	1–23	
36	Blue	Williamsville, Erie County, N. Y.....	On bed	.....	49,000	12,250	2.64	165.	0	
37	....do	....do.....	On edge .	.....	49,500	12,375	2.64	165.	0	

* See Nos. 64, 65, and 66.

Crushing-strength of marbles in two-inch cubes.

Number.	Kind.	Locality.	Position.	Cracked.	Strength of specimen	Strength per square inch.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.
				Pounds.	Pounds.	Pounds		Pounds.		
1	East Chester	Tuckahoe, Westchester County, N. Y.	On bed	.....	51,800	12,950	2.875	179.7	(*)	
2	....do	....do	....do	.....	48,200	12,050	2.875	179.7	(*)	
3	Common Italian	Italy	....do	.....	45,000	11,250	2.690	168.2	(*)	
4	....do	....do	....do	.....	52,250	12,062	2.690	168.2	(*)	
5	Vermont	Dorset, Bennington County, Vt.	....do	.....	30,450	7,612	2.635	164.7	1–17	Crushed with slight explosion.
6	....do	....do	On edge	.....	34,680	8,670	2.683	167.8	0	Do.
7	Drab	Mill Creek Quarry, Quincy, Ill.	On bed	.....	38,750	9,687	2.570	160.6	1–180	Crushed with louder explosion.
8	....do	....do	On edge	.....	39,150	9,787	2.510	156.9	1–74	Do.
9	....do	North Bay Quarry, Door County, Wis.	On bed	.....	80,100	20,025	2.800	175.	0	Crushed with quiet explosion.
10	....do	....do	On edge	.....	54,800	13,700	2.800	175.	0	Crushed with slight explosion; sand-cracks.

* The absorption of most appears so small, and occurs so slowly, that they were left for soakage hereafter.

Crushing strength of sandstones in two-inch cubes.

1	Brown	Little Falls, N. Y.	On bed	.....	39,400	9,850	2.250	140.6	1–34	Used in building Trinity Church, New York City. Had been exposed for years to weather and become harder. Broke suddenly, without previous premonition.
2	....do	....do	On edge	.....	36,600	9,150	2.250	140.6	1–34	
3	Gray	Bellville, N. J.	On bed	.....	46,800	11,700	2.259	141.	1–27	Broke suddenly.
4	....do	....do	On edge	.....	41,000	10,250	2.259	141.	1–27	
5	Brown	Middletown, Conn.	On bed	.....	27,800	6,950	2.360	148.5	1–40	Trinity Church, Brooklyn, N. Y., built of it.
6	....do	....do	On edge	.....	22,200	5,550	2.360	148.5	1–40	
7	Red	Haverstraw, N. Y.	On bed	.....	17,400	4,350	2.130	133.1	1–23	
8	do	....do	On edge	.....	16,100	4,025	2.130	133.1	1–23	
9	Pink	Medina, N. Y.	On bed	.....	69,000	17,250	2.410	150.6	1–55	Lilac in color.
10	....do	....do	On edge	.....	59,250	14,812	2.390	149.3	1–51	More purple than last.
11	Drab	....do	On bed	.....	70,900	17,725	3.420	151.1	1–70	
12	....do	Berea, Ohio	....do	.....	41,000	10,250	2.310	131.9	1–16	Very friable, like sugar.
13	....do	....do	....do	.....	33,200	8,300	2.130	133.1	1–20	
14	....do	....do	....do	.....	29,000	7,250	2.200	137.5	1–24	
15	....do	....do	....do	.....	31,000	7,750	2.110	131.9	1–19	
16	....do	....do	....do	.....	38,400	9,600	2.140	133.7	1–22	
17	Brownish-gray	North Amherst, Ohio	On edge	.....	21,800	5,450	2.140	133.7	1–19	
18	....do	....do	On bed	.....	26,600	6,650	2.190	136.9	1–19	
19	....do	....do	....do	.....	23,100	5,775	2.160	135.	1–19	
20	Drab	Vermillion, Ohio	....do	.....	33,800	8,450	2.160	135.	1–19	

21	....do.....	... do.....	....do....	.....	33 000	8,250	2 165	135.3	1-19	
22	....do.....	....do.....	....do....	.....	24.000	6,000	2 165	135 3	1-19	
23	....do.....	....do.....	....do....	.....	35,460	8 850	2 1 7	134 8	1-19	
24	... do.....	... do.....	....do....	.....	31,400	7,850	2 157	134 8	1-19	
25	....do.....	....do.....	On edge .	.....	27,500	6,875	2.157	134.8	1-19	
26	Purple.....	Fond du lac, Wis.....	On bed ..	.....	25,000	6 250	2.220	138.8	1-22	
27	do.....	....do	....do .	.....	24,900	6,225	2 220	138.8	1-22	
28	....do.....	....do	On edge .	.....	20,440	5.110	2 220	1 8.8	1-22	
29	...do.....	Bass Island, Wis	On bed ..	....	2 ,800	5.450	2 040	127.5	1-15	
30	....do.....	....do.....	....do ...	.....	17,000	4,250	2 040	127.5	1-15	
31	.. do	.. do	On edge .	... ...	17.150	4.287	2.040	127.5	1-15	
32	. do.....	Marquette, Mich.....	On bed ..	.....	20.200	5,050	2 285	142.8	1-32	
33	....do.....	....do	.. do----	.....	29,100	7,275	2.285	142.8	1-32	
34	....do.....	....do.....	On edge	.....	22.6 0	5,650	2 285	142.8	1-32	
35	....do.....	.. do.....	On bed ..	.....	29 800	7,450	2.160	135.	1-20	
36	....do.....	....do.....	....do ...	.....	29,800	7,450	2 160	135.	1-20	
37	....do	....do.....	On edge	.....	22,920	5,730	2 160	135.	1-20	
38	....do	....do.....	On bed ..	.....	21 000	5,250	2.170	135.6	1-20	
39	....do----	....do.....	do....	.....	25,080	6,270	2.170	135.6	1-20	
40	....do.....	....do	On edge	.....	19,000	4,750	2.170	135.6	1-20	
41	Red-brown.....	Seneca freestone, Ohio.....	On bed ..	.....	38,750	9,687	2.390	149 3	1-32	
42	...do	....do.....	On edge	.....	42,000	10.500	2 390	149.3	1-32	
43	Olive-green ...	Cleveland, Ohio	On bed ..	.....	27,200	6 800	2 240	140.	1-37	
44	....do.....	....do.....	On edge .	.....	31,640	7,910	2 240	140.	1-37	
45	Whitish	Marblehead, Ohio.....	On bed ..	.....	31,750	7,937	2.310	144 4	1-19	Rather a chalky limestone.
46	....do.....	.. do.....	On edge .	.....	27,400	6,850	2 310	144 4	1-19	Do.
47	Brown	Albion, Orleans County, N. Y.....	On bed ..	.....	54.000	13,500	2,420	151 2	1-44	
48	do.....	....do.....	On edge .	.....	45,400	11.350	2,420	151.2	1-44	
49	Pink.....	Kasota, Le Sueur County, Minn.....	On bed .	27,000	42,800	10,700	2 630	164.4	1-56	Calcareous sandstone.
50	...do.....	....do.....	On edge .	.....	46.700	11,675	2 630	164.4	1-56	
51	Light-buff	Fontenac, Goodhue County, Minn.....	On bed ..	... .	25,000	6,250	2.325	145.3	1-28	
52	...do	....do.....	On edge .	.....	31,100	7,775	2 325	145 3	1-28	
53	Craigleith.....	Edinburgh, Scotland.....	On bed ..	.....	48,000	12,000	2.260	141.3	1-34	
54	....do	....do.....	On edge	... ..	45.000	11,250	2.260	411.3	1-34	
55	Freestone	Dorchester, New Brunswick	On bed ..	.....	36.600	9,150	.....	.....	.....	
56	...do.....	....do.	....do ...	.....	37.650	9,412	.....	.....	.....	
57	Olive	....do.....	....do ...	.....	17,000	4,250	.....	.....	.....	
58	. do.....	....do	On edge .	... ..	24,200	6,050	....	.....	.....	

"on edge," broke into wedge-shaped disks of moderate size.

The Du Luth, dark granite (Nos. 73 and 74) split "on bed" into two disks nearly equal in size, which were forced a ½ in. apart, though pressed at right angles to their line of motion by a force of 68,000 lbs. The second specimen "on edge," acted in precisely the same manner. A very curious result of this experiment was the fact that the pine cushion blocks, which usually stand a pressure of 80,000 or 90,000 lbs., and become indented but comparatively not torn or injured, were in this case spread over the pieces *a* and *b* as though the wood had been crushed to fibre in liquid resin and painted over with a brush, part of it coming down in rough festoon between the separated parts of the stone.

But notwithstanding the diversity of phenomena attending the breakage of stones by direct compression, the obvious difference between the fragments produced by that operation and those fragments obtained by the stonecutter's hammer is suggestive of laws, modified but always existing, and capable of being, at least, roughly classified.

Specific Gravity.

The stones whose resistance to crushing pressure had been tested were also experimented upon in relation to their specific gravity. In the course of these investigations, it was sometimes necessary to be content with rather small fragments of stone, of not more than 15 to 18 pennyweight; but generally they weighed from 1 to 2 ounces.

On commencing this part of the work, some doubt was felt in regard to the best means of obtaining the correct displacement of porous stones; and all stones are more or less porous. It appeared evident that in weighing the stone first in air and then in water, an error would be committed by saturation. The first idea, to give the stone a coating of thin varnish, was abandoned, because, although the pellicle would be thin, yet no means could be taken to know precisely what its thickness was, or what it amounted to in its effects. The second idea, to soak the stone in very fluid resin, the pellicle to be washed from the surface before dry, was given up because it was desirable to preserve the specimens intact for experiments on freezing and other tests.

The plan finally adopted was, first, to remove from the stone all loose particles, and round off all sharp corners and edges, bringing it, in fact, practically to that condition commonly known as "water worn." It was then carefully weighed in air, immersed in water, and allowed to remain there un il all bubbling had ceased, and its weight taken. It was then taken out of the water and weighed again, in its saturated condition, with the precaution of previously denuding the stone of superabundant water by being compressed lightly in bibulous paper. The specific gravity is now found by dividing the weight of the stone when perfectly dry, by its weight in the air, after having been saturated, *minus* its weight in water.

This may also be expressed by the formula—

$$\text{Specific gravity} = \frac{W}{W_{//} - W_{/}}$$

W representing weight of dry stone in air; $W_{//}$ representing weight of saturated stone in air; $W_{/}$ representing weight of stone immersed in water.

In determining the specific gravity of stone, the weight of water was assumed to be 62½ lbs. per cubic foot.

Ratio of Absorption.

The term, "ratio of absorption," simply expresses the weight of water absorbed by the stone as compared with the weight of the dry stone; *i. e.*, if the stone, when dry, weighs 300 units, and the column of "ratio of absorption" shows the fraction $\frac{1}{300}$, it means that, by immersion in water, the stone will absorb 1 unit of it, weighing 301 units immediately after its removal from the water

The method adopted for ascertaining the specific weight of stone furnished at the same time the means to determine the "ratio of absorption." The weight of the saturated stone *minus* the weight of the dry stone gives, as a result, the amount of water absorbed. This might, perhaps, more correctly be called the "avidity of absorption," since it was limited to the period of bubbling. Some few stones, having been kept in water for several consecutive days, showed a slight increase in weight.

Since the capacity of a stone to absorb water has much influence on its durability, even during the warm season, and far more so in cold weather, the addition to the tables of this column was deemed advisable. (For tables see pp. 555, 556, 557, 558, 559.)

THE NATURE OF PROPERTY IN PATENTS AND THE LEGAL EFFECT OF THE ORDINARY FORMS OF ASSIGNMENT.

By EDWARD E. QUIMBY

Written for Van Nostrand's Magazine.

The ordinary form of assignment of an undivided interest in letters patent is as follows, to wit.:

"In consideration of one thousand dollars to me paid by A. B., of ——— I do hereby sell and assign to the said A. B., one undivided fourth part of all my right, title, and interest in and to the letters patent of the United States, No. — for an improvement in ——— ———, granted to me ——— the same to be held and enjoyed by the said A. B. to the full end of the term for which said letters patent are granted, and for the term of any extension thereof, as fully and entirely as the same would have been held and enjoyed by me if this assignment and sale had not been made.

"Witness my hand this —— day of etc.
"C. D."

It is settled that the privilege conferred by a patent is an incorporeal chattel impressed with the character of personal estate by being made assignable, and also that joint patentees or joint owners of a patent, in the absence of special agreement, are tenants in common and not co partners.

Hindmarch on Patents, Curtis on Patents, Clum vs. Brewer, 2 Curtis, 524, Parkhurst vs. Kinsman, 1 Blatchford, 496, Mather vs. Green, English Law Journal, vol. 35, p. 1, Vose vs. Singer, 4 Allen, Mass. R., 226.

An attempt to apply to tenancy in common in patents the rules of law defining the rights, powers, and duties of tenants in common in other kinds of property meets with great if not insuperable difficulties, arising from the peculiar nature of the property in question. A patent right is peculiar in having a defined period of existence, during which it is indestructible—unlike cattle, it is not liable to the uncertainties of animal life, and unlike vessels, it is not liable to shipwreck, neither can it be taken physical hold of and removed from the possession of its owner. Originally, as a rule, it has no ascertained money value The theory of its existence is that it is *sui generis*; there is, therefore, no rule of comparison nor principle of measurement for determining its money value. It may be made valuable by the employment of capital and labor in a skilful use of the privilege which it confers, or on the other hand it may turn out to be worthless and involve a total loss of the capital and labor expended upon it, irrespective of the degree of skill exercised. A ship may be wilfully burned or a colt wilfully killed by one tenant in common, in either case, who thus may totally destroy the common property. In such event the measure of damage to the other owners is easily ascertained, because, under similar circumstances, one ship has substantially the same value as another ship of like tonnage, materials and construction, and one colt the same value as another of like age, condition and strain of blood. But a patent right is a right to exclude all the world other than the grantees from the use of the privilege conferred by the patent, and there is no exclusion of any one of the grantees. One tenant in common cannot take away from his co-tenants their privilege without their consent. And exercise of the patent privilege by one tenant, instead of being a destruction of the common property, is usually a benefit to the other tenants by creating a demand for the thing patented, which they can take advantage of and participate in filling.

One of the elements of value in a patent right is its period of continuance. As the patent has a limited duration, the element of value suffers a conspicuous decrement from day to day. If the patent is commercially valuable, this value is at least discovered and established, if not created, by the act of exercising the patent privilege.

The ship may never have left the stocks, nor the colt its mother's milk, yet both ship and colt have an initial value, ascertainable by comparison, which may be regarded as so much capital representing the cost of building the ship or of breeding the colt. A patent right, on the contrary, derives its money value from a skilful exploiture which results in profit. An unskilful exercise of the privilege may result in loss irrespective of the utility of the invention, and it is no-

where pretended mere co-ownership creates any liability on the part of one tenant in common to contribute any portion of such loss made by another tenant in common. Yet the prevailing notion is that each owner of an undivided interest———————in a patent is necessarily entitled to a corresponding share of all profits derived from the use of the patent. This would only be true if it were so expressly set forth and provided for in the assignment, or by agreement between the co-owners. It is obvious that in this and in various other ways the title to the patent may be kept in its entirety, the element of exclusiveness be presented and the patent administered for the joint account of the several owners pro rata.

The only thing in the foregoing form of assignment tending to support the theory that an accountability is created among the owners, is the use of a fraction to designate the measure of their several interests. It will not do to predicate upon this alone a contract, agreement, or condition *pro tanto*, that all the owners shall share *pro rata* in profits which may be realized by either one from the successful employment of his own exclusive capital and skill when they are concededly not liable to contribute if loss results from the unsuccessful employment of capital in the exercise of the patent privilege.

Public interest has dictated the establishment of special rules of law governing tenancy in common in certain cases, and it has been well said with reference to shipowners, that "a personal chattel vested in several distinct proprietors, cannot possibly be enjoyed advantageously by all without a common consent and agreement among them and that the best method of forcing them to a common consent for their common benefit, is to leave it to themselves either to enjoy their common property by agreement, or to suffer it to remain unenjoyed or perish by their dissension."

The public interest in a patent right is not that the invention shall be locked up for the term of the patent, but that the patent privilege shall be exercised. The consideration for the grant is that something new and useful to the community has been disclosed by the grantee.

There appears to be an implied contract that the patent shall be exploited, and the public interest is clearly on the side of the part owner who either works the patent himself or licenses others to work it, and thus introduces the improvement into public use.

A patent has originally the character of a monopoly, and joint owners of it may, by agreement among themselves, preserve that character for it as against all the rest of the world; but it would be contrary to public policy to enforce such agreement when none such exists, it being to the interest of the public that there shall be competition among the owners tending to enlarge the production and reduce the cost of the thing patented.

In the absence of specific provision for perpetuating the monopoly, or, in other words, preserving the title to the patent in its entirety, it seems that assignees under the foregoing form are admitted by the grantee to the concurrent exercise of his patent privilege without liability to further payment or accountability therefor.

A privilege is a thing that a person has or has not; it is unsusceptible of division, and the privilege conferred by a patent is a mere naked right which would be inseparable from the person of the grantee but for the fact that every patent is by law assignable either as to the whole interest or any undivided part thereof. The fractional expression in the assignment determines the share of the respective owners in case of a sale of the entire interest by their consent, but no one owner can be compelled to consent to a sale nor be prevented from demanding any price he chooses for his interest, nor can his interest be sold and delivered without his consent. That is to say, each fractional interest is the subject of a distinct independent ownership. The property so shared was originally a right of the patentee to exclude all the rest of the world from the exercise of the patent privilege, *pro tanto* a right to remove the exclusion as to individuals, or, in other words, to license others to use the thing patented. By the act of assigning a part interest, the patentee gives up the right to exclude the individual who becomes his assignee, and, of course, the power of granting exclusive license rights thereafter; because, any territorial license right granted by the patentee thenceforth is taken subject to the condition that the assignee may step in and concurrently exercise the privilege of the patent in the same territory. Neither the patentee nor his assignee as co-owners of the whole interest, can be compelled to concur in grant-

ing an exclusive territorial license right, nor be prevented from demanding and retaining what consideration they may choose as the price of their assent thereto. Nor is there anything to prevent the coincident exercise of the patent privilege either by the parties themselves or by their legal representatives. By a common agreement among themselves, they may preserve the exclusive character of the right, and continue its exercise as a monopoly, or, by their dissension, they may permit that element of the value of the patent to perish.

Bearing in mind that the patent privilege includes the right of licensing, the legal proposition may be thus stated:

Patent property consists of an assignable privilege, having originally an exclusive character which may or may not be preserved at the pleasure of the grantee. If the grantee assigns an undivided part interest in his patent without the precaution of exacting an agreement regulating the use of the privilege assigned, he, by that act, divests himself of the sole power of exclusion which he theretofore possessed, and the common property thenceforth is simply a common privilege, the free exercise of which by either part owner cannot be held to be an invasion or infringement of the rights of the other part owner.

This state of things may be remedied and the rights of the parties preserved by a special agreement between them, or by a territorial division of the patent, or by assignment of the whole interest to a trustee empowered and directed to administer the patent for the account of the several owners, pro rata.

RAILWAY GIRDERS FOR THE METRE GAUGE.

From "The Engineer."

The designing of iron girders of long span, which are intended to carry comparatively a very light rolling load, is, in an economical point of view, an unsatisfactory task for an engineer. It is, in fact, well nigh impossible to combine the requisite elements of strength and stiffness without sacrificing some material in one or other, or probably in both. In a skilful and judicious design, especially adapted for the particular duty it has to perform, and not modelled after an old stereotyped pattern, a considerable amount of the material constituting essentially the strength of the structure, may be made useful in insuring to some extent the other equally necessary element. But unfortunately, on the other hand, material employed solely as bracing, or with a view to obtain stiffness, cannot be rendered serviceable to resist strains, which must be provided for by so much actual metal in the flanges and web of the girder. A prevailing fault in many of the girders designed for this relative proportion of the different loads to which they are subjected, is that while the element of strength is insured to a superabundance, that of stiffness is considered to be necessarily extraneous. In a word, the girders are built first and stiffened afterwards. A precisely analogous instance frequently presents itself in edifices in which true esthetical principles are departed from. The building is constucted first and ornamented afterwards. No doubt, in the first case, some rigidity must be provided subsequently to the erection of the girders; and, in the second, some ornamental details and embellishment must be added after the building, in a structural sense, is completed. But the addition of a minimum amount of stiffness to a girder by extraneous bracing, and the similar addition of surface decoration to a large edifice, are very different things from totally ignoring these details in the design of these two classes of structure. The economical merit of any particular type of girder will depend, not, as is generally considered, upon the actual amount of material in its flanges and webs, but upon the total amount required for a pair of them when they are braced together so as to constitute a bridge.

In investigating the type of girders best suited to fulfil the double conditions of a long span and a light rolling load, we shall omit the solid-sided, or plate form, for two reasons. In the first place, there is no economy in the employment of this description of girder, even in very small examples, when compared with the open web or trussed form; secondly, the impossibility of uniting the flanges and web with any mode of connection except rivets, renders it

inapplicable to those cases where from various causes, pins must be used for that purpose. We always have advocated the used of rivets when possible instead of pins, and see no reason to change our opinion. At the same time, we freely admit that cases may arise where the latter means of connection are the only ones available. The ordinary form of open web girder adopted for India, in which country the metre-gauge will have a great scope, is either the Warren or the lattice, in which the upper and lower flanges are horizontal. In every girder in which this horizontality of the two flanges obtains, there is a loss of metal towards the ends, and it is impossible to avoid it. As the span increases this loss also increases, and is still further augmented by the special considerations under notice.

For the sake of example, let us select a girder of a span of one hundred and fifty feet. The breadth of the top flange, if built of the ordinary trough shape, cannot be less than thirty inches, and the minimum thickness of a single plate half an inch. In addition, there are the side plates and angle iron by which the web is attached, which must be continuous throughout the whole length of the girder. Allowing for all possible reduction of sectional area in the side plates, there will still be, at least, thirty inches of gross sectional area at the ends, a quantity greatly in excess of the theoretical requirements. Now for the web. The rolling load for one girder of this span, according to the data prescribed for Indian bridges by the Government, is fifty-eight tons, or only a trifle over one-third of a ton per foot run. In a girder of this size the bars in the web would be double, and supposing them inclined at 45 deg., the strain upon each central bar would be just five tons, requiring theoretically only one inch of sectional area. It is needless to observe that a bar nearly fourteen feet long, under these circumstances, must have a sectional area four or five times this amount to fulfil practical exigencies. In a bridge a mile long, of which there are several examples in India, and in which the girders are of the horizontal type, the loss of metal from these two circumstances combined must be enormous. There are, notwithstanding, many practical advantages possessed by the horizontal girder which must not be underrated. It is neat in appearance and simple in construction. All the bars, with the exception of a few terminating over the end pillars, are of the same length, and inclined at the same angle, so that but few templets are required. It also possesses the merit of being able to be loaded on either flange, or on both at the same time, so that in the latter event two roadways can be taken over it, of which there are several examples in India and other foreign countries.

The objection against the loss of metal at the ends of the flanges on the horizontal girder is very successfully met, when the bridge consists of some half dozen spans, by making the girders continuous. The loss then is confined to the two obtuse ends, and is trifling in a bridge of many spans. The ends of the otherwise individual girders are now rendered continuous over the piers, and all the metal in the flanges is utilized. Moreover, the principle of continuity is extremely well adapted in an economical point of view to the conditions of the problem before us, which include a relatively large span, that is, a heavy permanent or dead load, with a light live or rolling load. Under these circumstances the position of the points of contrary flexure, or points of inflection, alter very little under the action of the passing load, and the full benefit of the continuous system is obtained. But in order to benefit by this happy proportion between the permanent and the rolling load, one other point must be satisfactorily settled. It is an essential feature of the continuous principle that the foundations should be of the most stable and unyielding character. A slight settlement in a pier or abutment, which would produce no injurious effect upon independent girders, would completely destroy the efficacy of continuous ones, and altogether obviate the peculiar advantages to be derived, in such an instance as the present, from the adoption of the principle. The foundations in India are notoriously insecure, and it would be obviously a most injudicious plan to employ as a rule continous girders in such a country. The adoption of the continuous system will not make any difference with regard to the loss of metal in the web already referred to.

Returning to the theoretical part of the subject, the object to be aimed at in designing girders for the purpose in point, is evidently to select such a form as will enable the strains upon the flanges to be more equalized and more uniformly distributed, and those upon the central part of the web

bars to be either increased or confined to one character, compressive or tensile, but not both. The type of girder which fulfils the former of those conditions with respect to the flanges is the bow and string, and with proper adjustment it may be caused to fulfil those also required with respect to the central bars of the web. In the bow and string girder the strains on the bow and string are practically uniform throughout, so that there need be no loss of material in the flanges.

It will be seen on a little investigation that this form of girder presents advantages for very much reducing, and in some instances, for entirely obviating the loss of material which occurs in the web of parallel girders. Under any conditions of loading the strains upon the bars in the web of a bow-string girder are very considerably less than in those of a parallel girder placed under similar conditions of span and loading. With a uniformly distributed static load the strains upon the bars are all tensile, but so soon as a rolling load is brought upon the structure they are subjected to a compressive strain to a greater or lesser extent, according to the successive positions of the load, and the necessity for counterbracing these is at once apparent. If the proportion of the permanent to the rolling load could be adjusted so that the tensile strains upon the bars, due to the action of the former description of load, were always in excess of those produced by the latter, there would be no necessity for counterbracing. Thus, not only would the sectional area of the web be reduced to nearly the theoretical amount, but one of the great difficulties in the economical designing of these structures removed, namely, the securing of long struts from deflection. Having admitted that all girders, both separately and when combined so far as to constitute a bridge, require a certain amount of extraneous bracing, it remains to investigate whether a pair of parallel or a pair of bow-string girders require the most bracing. One practical objection against the bow-string is that it can only be loaded on the bottom flange; therefore in comparing the two as a bridge, the assumption of loading on the lower flange must be conceded.

The depth of the parallel girder is constant, so that when the girders are deep enough to be braced together overhead, the bracing must be continued at intervals over their whole length. This is not the case with the bow and string, whose maximum depth at the centre is equal to the constant depth of the parallel girder, so that one bracing overhead would be required only in the immediate vicinity of the centre. Moreover, the liability to vibration of a girder whose depth diminishes regularly from the centre to almost nothing at the ends, is manifestly very much less than that of another form in which the depth is constant, and the ends free to move with a leverage equal to that depth. On the whole it appears that the bow and string is the preferable form for girders for the metre gauge, even if the parallel girders were made continuous. As independent girders they are, no doubt, inferior to the other type.

There are one or two other forms of girders well suited to this particular proportion of dead and live load, which we shall refer to on another occasion. As the metre gauge is now definitely adopted for many Government railways in India, the subject of the most suitable form and principle of truss for the purpose is deserving of all consideration.

ENGINEERING INSTRUMENTS OF ALUMINUM.

By S. V. CLEVENGER.

Written for Van Nostrand's Magazine.

When this beautiful metal was too costly to warrant its being generally used for the innumerable purposes to which it is adapted, there was a good reason for its being neglected by manufacturers of scientific instruments, but since the mode of its production was so much simplified by Bunsen and Deville, causing its value to fall from £3 in A. D. 1856, to 11s. per oz. in the succeeding year, it is unaccountable that aluminum should not be utilized in the construction of some, at least, of the appliances to which, above all metals, it is so well suited.

Take the single item of engineering instruments where weight is an objection and increased size within certain limits desirable.

The ordinary transit weighing eleven pounds, may be made of aluminum to weigh three pounds without decreasing its

size or increasing its cost, or the arcs may be made five times as large under the same weight; the solar compass could have all the advantages arising from diminished liability to errors of reading, and the certainty of readily determining fixed or variable errors of graduation or construction.

Aluminum has many advantages over brass, silver, nickel and steel, and combines all their qualities without their objectionable weight, and a simple statement of its various recommendations to instrument makers will be all that is needed to make it known as theoretically the metal for the purpose.

Its lustre is bluish white.

It is non-magnetic and therefore will not deflect a needle by its presence.

It can be electro-deposited.

Its price is one-half that of good silver.

It neither rusts nor tarnishes so readily as brass, unless when in very thin sheets.

It is not acted upon by air or water at common temperatures, damp air slowly tarnishing it. When intensely heated in a current of air it suffers only slight oxidation; heated to redness in an atmosphere of steam it slowly oxidizes.

It is readily acted upon by hydrochloric acid which evolves hydrogen and forms chloride of aluminum. Sulphuric and nitric acids do not affect it at common temperatures, but when boiled in the latter it oxidizes as long as heat is maintained. Boiling in acetic acid does not affect it. Concentrated alkaline solutions slowly oxidize it and hydrogen is liberated. It is not affected by sulphur or sulphuretted hydrogen, or by solution of the alkaline sulphides.

The alloys with other metals are too brittle to be made use of for the purposes of this article.

Atomic weight 27.5; specific gravity, 2.67 when rolled, when cast, 2.56.

It is more malleable than tin, platinum, lead, zinc or iron, being next to copper, and less malleable than gold or silver.

Next to copper it is more ductile than zinc, tin and lead, and less ductile than gold, silver, iron and platinum.

Compared with other metals under the same bulk, aluminum weighing 1.

Platinum,	7.9	Gold, .	7.7
Mercury, .	5.4	Lead, .	4.5
Silver, . .	4.1	Copper, .	3.6
Nickel, . .	3.6	Iron, .	3.1
Tin, . . .	2.9	Zinc, .	2.8

Its electrical conduction is greater than that of iron or zinc, being 33.76 where silver is 100.

Its fusibility is at a point little less than that of silver, 1750 deg. Fahr.

Dr. Clemens Winkler, in the "Deutsche Industrie Zeitung," says it can be worked into any shape, and that there are no deleterious effects arising from working in it.

It is largely manufactured in England and France, there being a large factory at Newcastle, where it is extracted from the French mineral *Vauxite*.

New methods are being discovered for obtaining it from kaolin or clay, inexpensively, and considering that it combines the ductility and malleability of copper, with vastly more than the strength of steel (it is placed by some as 13 times stronger) with the lightness of chalk, it certainly should take the place of metals less adapted to purposes where strength, lightness and bulk are desiderata, as is indisputably the case in the manufacture of fine instruments for engineering field use.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—October 21, 1874.—A stated meeting was held at 8 o'clock P. M. Prof. Robert H. Thurston read a paper on the "Efficiency of Furnaces burning wet Fuel," which was followed by discussion.

Attention was called to two pieces of one of the main cables of Fairmount Suspension Bridge (Philadelphia), erected by Ellet, about 1840—one from near the centre of the span, and the other from over the top of the tower—which, with a communication from the donor, Mr. Joseph M. Wilson, of Philadelphia, referring to them, were presented to the Society.

November 4, 1874.—The twenty-second annual meeting was called to order at 11 o clock A. M., Mr. Julius W. Adams, President, in the chair.

The Annual Report of the Board of Direction on the affairs, and of the Treasurer on the finances of the Society, were read and accepted.

The Society proceeded to elect officers for the ensuing year; ballots were taken and the following declared elected: Messrs. Julius W. Adams, President; W. Milnor Roberts and Theodore G. Ellis, Vice Presidents, Gabriel Leverich, Secretary; James O. Morse, Treasurer; Octave Chanute, John Bogert, Charles Macdonald. Francis Collingwood, and George S. Greene, Directors.

A recess for one half hour was taken.

The meeting was called to order at 2 o'clock P. M. The amendment to the By-Laws, Section 23, submitted at the last regular meeting of the Society, was taken up; the President, as chairman of the "Committee on a Revised Constitution," presented a report thereon, and the proposed section was adopted instead of the one in force.

On the recommendation of the Board of Direction, the fee henceforth to be paid by Fellows,

under Article xxvi. of the Constitution, was reduced from $250 to $150.

The President, for the "Board of Censors to award the Norman Medal," reported:

"The undersigned, a Board of Censors to select from the papers submitted in competition for the Normal Medal, such one as in their judgment best meets the views of the founder and the true interests of the Society, beg leave to report, that the 'Memoir on the Construction of a Stone Dam,' a paper submitted without other mark of identification, is entitled to the Norman Medal for 1874. Julius W. Adams, President American Society of Civil Engineers; John G. Barnard, Colonel of Engineers and Brevet Major-General U. S. A."

The sealed envelope accompanying the paper named was opened, and Mr. James R. Croes, of New York, declared the successful competitor.

Mr. Alfred P. Boller, chairman of the committee on "Time and Place of the Seventh Annual Convention," made a report which was accepted. Communications from Mr. William P. Shinn, of Pittsburgh, and others, relating to the matter, were read. A discussion followed, and it was determined that the Convention should be held June 9th and 10th next, at Pittsburgh, Pa.

A report of progress from Mr. W. Sooy Smith, chairman of the committee on "Tests of American Iron and Steel," was presented and accepted; and to promote the objects in view the committee was requested to arrange for a general meeting of members of the Society, in Washington, during the next session of Congress.

Mr. Thomas C. Clarke, of the Committee on the "Means of Averting Bridge Accidents," stated that a report had recently been prepared by one member, which, from lack of time, had not been examined by others of the Committee, and under advice of his colleagues present, he would simply report progress.

Mr. John Bogart, chairman of the committee on a "Change of the Society's Rooms," presented a report which was accepted, the committee continued, and the Board of Direction instructed to secure more commodious quarters for the Society, at the expiration of the lease of the rooms now occupied.

The Committees—on a "Plan for the Increase, Maintenance, and Preservation of an Engineering Library and Museum;" on a "Comparative Examination of the principal Pumping Engines in Use;" on "Founding a Testing Laboratory;" on "Securing a National Recognition of the Society," and on "Railway Signals; severally made reports of progress.

IRON AND STEEL NOTES.

A Valuable Present to Lafayette College.—The Swedish Administration of the Iron Office has sent to Lafayette College a complete collection of the famous iron ores of Sweden, and their productions. The large boxes containing this collection arrived at Philadelphia last week in the ship Adolf Fredholm, and were delivered to the college by the Custom House officials, free of charge. This extensive and valuable collection is a duplicate to the one given some years since to the Royal School of Mines, in England, by the Swedish Government. It will be of special value and interest to the iron masters of Pennsylvania, and the college authorities intend to make it accessible at all times for their examination. We understand also that the professors of Lafayette are selecting from the duplicates in the college cabinets a complete collection of American ores, to be presented to the Swedish Administration in return for the one received by them.

Improvements in Furnaces and Processes.—Puddling apparatus is the object of improvements claimed by Sir J. G. Newton Alleyne, Bart., of the well-known Butterley Ironworks: these relate to partial rotary furnaces, such as are constructed with a revolving basin as a bottom, in combination with special rabbles for use in connection with the same. The bottom is made double, carried and rotated by a hollow shaft, within which a pipe is fixed with jets, for conveying water into the hollow space of the bottom, to play upon and cool the upper shell thereof, which forms the bottom of the puddling furnace; the water is conveyed away by a suitable outlet at the bottom of the tubular shaft. The rabble is made to stir the molten metal more effectively by means of a rotary or reciprocating action, suitably communicated to it, and is formed with a number of tines projecting from the stem down into the molten contents of the rotating basin.

Messrs. W. Blackett Haigh and A. Bleasby, of Oldham, have improvements in the construction of cupolas and furnaces for melting iron and other metals, such as are formed with chambers or receivers for the metal as run, and provided with an outlet flue into the atmosphere for the spent combustion products. Their proposal is to utilize these waste gases, by returning the heat and flame to the interior of the cupola or other furnace, partially to aid in melting the metal; and the apparatus consists of one or a number of tapered vertical pipes communicating with the receivers or chambers, and connected with a similar number of inclined or horizontal pipes conducting to the interior of the furnace, and they claim hereby to avoid the nuisance at present created, and at the same time keep cleaner the inside of the cupola or other furnace.

Improvements in the iron-smelting process and appliances are claimed by Mr. W. A. Lyttle, engineer, of The Grove, Hammersmith. As regards the charge, the inventor proposes to pulverize the ore and fluxing materials with a certain proportion of carbonaceous matter, and incorporate the whole by means of hydraulic cement into solid masses or lumps, like concrete or mortar. These blocks are then placed in the ordinary smelting furnace, in layers alternating with such a proportion of ordinary or other fuel as may suffice in conjunction with that contained in the blocks to effect the complete and thorough reduction of the ore incorporated therewith. As regards the smelting furnace itself, he provides a supplementary fuel or combustion chamber, exterior to the furnace, with an opening into the furnace opposite the blast-pipe nozzle, whereby bituminous coal, coal dust, or other suitable fuel may be employed, in quantity readily regulated, to be burned under the impact of the blast and supply heat; and the fuel chamber is provided with a feed-hopper, rod, and alarum, to indicate when the fuel requires to be re-

newed therein, by the descent of the rod, as the fuel is burnt away, acting on a bell.

Messrs. S. Newton, of Dudley, and C. Newton, of West Bromwich, introduce improvements in the construction of puddling furnaces for the manufacture of iron and steel; consisting in means for the maintenance of a continuously flowing current of water to keep the bed of the furnace at a low temperature and prevent injury by the heat. For this purpose wrought-iron U-shaped pipes are imbedded in the cast-iron plates forming the bed of the puddling furnace, or similar pipes are formed therein in the casting process; the ends of these wrought-iron pipes or cast-iron cavities are united by suitable junction pieces, and the continuous channel, formed in the bed of the furnace thereby, is formed preferably in a zigzag or tortuous course, so as to obtain a considerable area of cooling surface.—*Iron.*

RAILWAY NOTES.

RAILWAYS IN EUROPEAN TURKEY.—The opening of another section of the Salonica and Uskub Mitrovitza railway—a line now approaching completion—is an event of great importance, not only as regards the inhabitants of the fertile, but little known Turkish provinces through which it runs, but also for us, says an English exchange, inasmuch as, when the main line shall have been completed, and the proposed junction with the Austro-Hungarian lines effected, it is by no means improbable that Salonica may become the most convenient port of embarkation for India and the East. The distance from Salonica to Mitrovitza, on the borders of Bosnia, is 361 kilometres, of which 25, making a total of 268, have just been opened; and the contractor, Signor Bariola, calculates on being able to complete the line to Mitrovitza by the end of August. The railway, in its course, is carried through 11 tunnels, of an aggregate length of 1,400 metres, and by means of 47 bridges (the total length of which extends to 2,545 metres) over wide streams which have not for ages been spanned by man. The rails have been obtained from England and France; the rolling stock has been furnished by Belgium and Germany; and the scientific and working staff, including engineers, masons, carpenters, smiths, etc., have come from Italy, with the contractor, Signor Bariola, who is himself an Italian; while the common kind of labor has been provided by the inhabitants of the countries through which the line has passed. —*Iron Age.*

ENGINEERING STRUCTURES.

IMPROVEMENT OF THE LOIRE.—The great proposed work of the amelioration of the river Loire from Nantes to the sea has been reported on by a commission of four inspectors-general. The report declares the condition of the river to be intolerable; there is only 4m. 30 depth of water, at the low tides, and often not more than 3m. 60, and the navigation demands 6m. 50. Two plans were before the commission—one by M. Carlier, who proposes a lateral canal, the cost of which he estimates at 89,000,000 fr.; the other, by MM. Partiot and Lechalas, who declare that the river may be improved and dredged to the desired depth for 49,000,000 fr. The execution of this work has been under discussion for years; in 1851, especially, plans were drawn up for a system of dams to narrow the bed of the river, and convert the sides into reservoirs for the purpose of scouring it. A portion of this scheme was carried out between 1859 and 1864 with good effect; but in 1872 the high tides reduced it to the lamentable condition it is in at present. M. Carlier proposes to cut a canal to the right of the river, 30 metres wide at bottom with a profile varying from ½ base to 1 in height in the rocky portions, to 5 to 1 in the soft mud. His plan is to execute the canal in three portions, each communicating at both ends with the river by means of locks, so that they may be executed and used separately. The three sections are—the river portion proper, 12,400 metres long; the intermediate portion, 25,900 metres; and the maritime portion, 12,500 metres; in all, more than 30 miles. He proposes to construct the middle section first, hoping that possibly the upper part of the river may be deepened by dredging, and thus the upper section of the canal rendered unnecessary; which hope, however, is not shared by the chief engineer, M. Watier. It must be added that whatever plan is adopted of obtaining a depth of more than six metres of water, and thus admitting large vessels, will require the construction of a basin at Nantes, which is estimated by M. Carlier to cost 27,0 0,000 fr., and is included in his total of 89,000,000 fr. The commission considers the estimates of M. Carlier as untrustworthy, and say that in such works the unexpected generally exceeds what was calculated, and the proprietors of the lands contiguous to the river complain that the canal will prevent the high tides from flooding and fertilizing the low grounds on the right bank of the river, thus reducing the value of rental from 200 fr. per hectare to, perhaps half that amount. The commission believes further that the bad composition of the soil would probably cause the excavation to turn out a "bottomless gulf to swallow up the Government money," and report against the project. The particulars of the plan of MM. Partiot and Lechalas we must defer for the present.—*Iron.*

ORDNANCE AND NAVAL.

TRIAL TRIP OF THE "CITY OF TOKIO."—The engineers' trial trip of the Pacific Mail Company's steamship City of Tokio, Capt. J. Maury, was made on Monday, Oct. 19, and was in all respects a decided success. She is the exact counterpart of the City of Peking. It is almost needless to say that both ships reflect the highest credit upon all parties concerned, and excite the warmest admiration of all who see them.

The City of Tokio left her dock at half-past ten, having on board about two hundred and fifty invited guests.

Owing to a strong northwesterly wind which was blowing at the time, a considerable delay was occasioned in starting, but at a little before eleven o'clock her engines began to move, and from that time until her return to the city the bell was not once rung for stopping, except in testing her engines and turning the ship, to ascertain how she backed and how she went ahead. Her route was

down to the Southwest Spit, out to sea, round the Light Ship to Squan Beach, and thence back to the city, which was reached between five and six o'clock. Nothing occurred during the entire trip to mar its pleasure. The engines worked admirably and were praised in loud terms on all sides. She was not speeded at any time during the trip, and the throttle-valve was not more than half opened. The best time made, as reported, was at the rate of fifteen knots over a measured mile, while making fifty-three revolutions. The engines were reversed in fifteen seconds. The turning in a full circle occupied a little less than twelve minutes. It was noted that probably no ship ever had on her trial trip so many professional engineers, or so many competent to form a critical judgment, and also that their criticisms were all highly favorable to her arrangements and workings.—*Nautical Gazette.*

BOOK NOTICES.

No. 11 Science Series.

THEORY OF ARCHES. By Professor W. ALLAN. Price 50 cents. New York: Van Nostrand.

This is a small but very convenient and comprehensive compendium of Prof. Rankine's chapters on the subject of arches, but more thoroughly explained and amplified. The book, as of necessity it must, infers a considerable mathematical knowledge on the part of the student, as far as conic sections and the differential calculus. We hope that this fact will not remove it out of the reach of many civil engineering students, more especially of the rising generation. The subject is exhaustively and clearly considered, all cases of variety of loading being, as far as possible, given. The estimation of the various forms of arches is very clearly introduced by first using the converse of each case—a string loaded in all varieties of manners, the pressures resolved and analyzed, and the form of curve which the string will take deduced and expressed by a suitable linear equation. In this way, the curve of a string loaded in any given manner being arrived at, it is a simple deduction that an arch in its ultimate shape to resist similar but opposite strains must have the same curve. In conclusion, we will give this little handbook the rare credit of not being unnecessarily discursive or wearisome, containing the necessary information to construct, under almost every condition, and no more, so that he who buys it gets the maximum amount of information on the definite subject, with the least quantity of padding, for his money.—*Iron.*

In this little treatise, which forms the 11th No. of the publisher's "Science Series," the author takes as his model the method adopted by the late Professor Rankine of investigating the subject, and introduces amplifications and explanations of his own. He, in the first place, makes the ordinary assumption that the arch may be represented by a chain or cord, and the strain theoretically investigated. By reversing the cord, and supposing it replaced by a thin metal strip capable of resisting a compressive strain in the direction of its length at any point, we obtain the "linear arch, or rib." Practically this particular description of arch has no existence, but it forms the basis from which the form of equilibrium for actual arches of construction may be determined. Thus, knowing the form which would be assumed by the linear arch under any given disposition of load, the line of resulting pressure can be found for a real arch. The author investigates also the principle of the geostatic and hydrostatic arches. We think a division of the contents of the little volume into chapters or sections would facilitate the perusal of it.—*The Engineer.*

QUANTITIES AND MEASUREMENTS. HOW TO CALCULATE THEM. By ALFRED C. BEATON. Fourth Edition, Revised and Enlarged. London, 1874. For sale by Van Nostrand. Price 60 cents.

Weale's series of handbooks have long been favorably known to many sections of the scientific and industrial public; and among the best and most useful of them may be classed this of Mr. Beaton's, which relates to all kinds of artificer's work, and is calculated, from the easy, methodical, and ready formulæ which it contains, to be equally serviceable to the experienced workman and the apprentice, to the master artificer, the surveyor, and the architect. The present edition contains, over and above what was to be found in previous ones, carefully prepared lists of prices for work in all branches of the building trade.

EARTHWORK TABLES. By JOSEPH BROADBENT and FRANCIS CAMPIN, Civil Engineers. London, 1874. For sale by Van Nostrand.

These tables, which were in the first instance prepared by the authors for their own use, and have therefore passed the test of actual experience, show the contents in cubic yards of embankments, cuttings, etc., of heights and depth up to an average of 80 feet, in order to facilitate the accurate determination of earthwork quantities in estimates for permanent work; and we have no doubt that they will be found useful by contractors and others. They are printed in a clear and legible manner, and full instructions for their use are prepared.—*Iron.*

LA GEOLOGIE DE LA FRANCE.—By M. AMÉDÉE BURAT, Professor of Exploration of Mines in the Central College, France. Paris, 1874. For sale by Van Nostrand. Price $6.40.

This interesting work contains special notices and descriptions of every region of France. Nevertheless, we must say, a certain acquaintance with the study of rocks is required, in order to completely understand M. Burat's work and profit by its perusal. The author has divided his work into six chapters, and adopted an excellent plan to embrace at once the whole geology of the country. At the commencement he gives, under the title of a geological chart, the description of the manifestations of each of the phenomena which have overturned the ground at the different epochs of disturbance; then he follows each geological formation in the order of the scientific classifications, studying each of them in the different regions where they may be met with, and tracing them from remote ages downwards. He passes in review, each in a separate chapter, the mountainous parts of the country, where are found granitic lands mixed with transition lands, and the porphyritic and volcanic lands, thus closing the series of primitive rocks. The three last chapters are dedicated

to the succeeding regions, in which we are more especially interested, where the coal fields are situated or the secondary formation), which are placed immediately after them in the geological order, and lastly, the tertiary formation and alluvial lands, which complete the earth's crust as it appears in France.

SHORT LOGARITHMIC AND OTHER TABLES INTENDED TO FACILITATE PRACTICAL CALCULATIONS, AND FOR SOLVING ARITHMETICAL PROBLEMS IN CLASS. London, 1874. For sale by Van Nostrand.

The dozen pages before us contain the logarithms of numbers as far as 1600 to five places of decimals, together with various short tables constantly used by engineers in their professional calculations. The tables of "Useful Multipliers," and "Multipliers for conversion of English and French measures," will be found valuable, and will very much facilitate that description of labor which is not only entirely unprofitable, but of all others the most liable to error. The contents comprise tables of the weight of the ordinary constructive materials, squares and cubes, and areas of circles. —*The Engineer.*

TABLES FOR TRAVELLERS; ADAPTED TO THE POCKET OR SEXTANT CASE. Compiled by ADMIRAL BETHUNE. C. B., F. R. A. S., F. R. G. S. Second Edition. Edinburgh and London: W. Blackwood & Sons.

The handy little pocket companion before us is intended to supply the want of books of reference to mariners or scientific travellers under obvious contingencies. Bailie Nicol Jarvie sagely observed that even a Glasgow magistrate could not expect "to carry the comforts of the Sautmarket at his tail" in Rob Roy's country, and members of both the useful classes which we have named, often find themselves in positions in which a library of reference is out of the question. Under such circumstances Admiral Bethune's booklet, which may be stowed in the sextant case or waistcoat pocket, supplies the want of many volumes, containing, as it does, tables and other formulæ to assist in finding the sun's right ascension and declination, lunar and planetary corrections, tables, and logarithms, methods for finding the latitude and time, and solutions of quite a number of other and almost equally important problems.

IRON AND TIMBER RAILWAY SUPERSTRUCTURES AND GENERAL WORKS. By J. W. GROVER, M. Inst. C. E. London. For sale by Van Nostrand. Price $17.00.

This work consists of some forty lithographs of timber and iron bridges, together with some specifications for ordinary railway works and permanent way. We cannot congratulate the author upon the style of his designs. With one or two exceptions of timber superstructures, all the designs—which are of the open web type—have three sets of bars in the web, one in a vertical and two in a diagonal direction. Every scientific engineer is now well aware that one of these three sets is superfluous, and its employment simply signifies so much waste of material. Timber trusses, and those of iron on a very small scale, such as gantries, are exceptions to this rule. Gibbs and cottars, in our opinion, do not form suitable connections for bridges of spans of 40 ft. Mr. Grover confines himself strictly to girders of only one type—those with open webs and parallel top and bottom flanges—if we except a couple of pages devoted to skeleton elevations of plate girders. The volume is well printed and the lithographs clear, especially the lettering and dimensions. A glance at page 23 will best show the manner in which the text is arranged. We question the good taste of an author including in what are intended for model specifications one of his own "steel spring washers" as an essential item of permanent way. It is a common mistake in getting up books to crowd too much matter in too small a space. In the volume before us it is manifest that the opposite extreme is equally possible.

MISCELLANEOUS.

THE GRAPHIC REPRESENTATION OF STRAINS IN BEAMS.—Mr. John Neville, C E., M.R.I. A., read a paper at the meeting of the British Association on "The Vertical Shearing Stress of Beams and the Point of Maximum Bending Moment," explaining a new method of discovering the stress by graphic methods. The following is an extract of the paper:—

The vertical shearing stress of a beam at any point is known to be equal to the weight on the next pier less the weight lying between this pier and the point. It is generally represented graphically for each point by ordinates to the line of beam on one side only. Now, as the sum of these stresses must be zero, those on one side being positive and those on the other negative, the proper graphical representation is to show them according to these signs above and below the line of beam. This leads to a simple geometrical construction for finding the shearing stress when the beam is loaded in any way with a number of weights, single or distributed. Find the line of shearing stress for the beam itself; then using this line plot on it the line of shearing stress for the first weight, making the ordinates vertical to the line of beam itself. Plot from this second shearing line a third shearing line for the second weight, and so on. The shearing line last found gives the stresses arising from the weight of the beam and the weights for each point. The construction gives the line of shearing stress at each step, and for each weight also.

When the shearing is a maximum the bending moment is zero, and where the shearing stress is zero the bending moment is a maximum; consequently, that point where the line of shearing stress intersects the beam is that of the greatest bending moment.

The areas between the line of beam and the line of shearing stress above and below are equal

AN esteemed Paris contemporary in concluding a review of the French railways, says, that "the Suez canal, the St. Gothard tunnel, and the series of European railways, are evidently directed against France, the object being to take from her the transit business of England," and that it is the duty of France to establish such relations with England that the advantage of shorter distance may turn to the profit of the former, and preserve to her the transit which makes the prosperity of the great lines of railway.

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